

## 2 STORMWATER MANAGEMENT

### 2.1 INTRODUCTION

- A. The following section has been established to assist developers and engineers with the design, construction and maintenance of stormwater (private and public) infrastructure within the jurisdiction of the Town of Wake Forest. The methods, procedures, design factors, formulas, graphs, and tables presented in this section are intended to establish minimal guidelines for residential, commercial and industrial storm drainage design, and for the solution of drainage problems involving determinations of the quantity of runoff, rate of flow, method of collection, storage, and conveyance of storm water. The Town of Wake Forest believes that the following criteria are sufficient to ensure the welfare and safety of the general public and to protect the economic investment of the citizens of our Town.
- B. Alternative design methods may be considered by the Engineer/Designer on a case-by-case basis; however, there should not be extensive variations from the criteria and procedures within this division without the expressed approval of the Town's Engineer.

#### 2.1.1 TOWN ENGINEER

The Town Engineer shall be responsible for interpretation and implementation of the stormwater management and design criteria for the Town of Wake Forest. Approval from other applicable agencies may be required.

#### 2.1.2 STORM DRAINAGE POLICY

It is the policy of the Town of Wake Forest that all developed land within the Town jurisdiction have adequate stormwater facilities and controls to protect, maintain and enhance the public health, safety, environment and general welfare in order to control the adverse effects of increased post-development stormwater runoff and nonpoint and point source pollution associated with new development and redevelopment.

The Town may accept stormwater management systems for maintenance if the system provides drainage for streets that have been accepted for maintenance by the Town Board and have been designed and constructed in accordance with the provisions of this manual, the Unified Development Ordinance. The latest revision to the following documents which are herein made part of this manual by reference:

- North Carolina Erosion and Sediment Control Planning and Design Manual  
<http://portal.ncdenr.org/web/lr/publications>
- NCDENR Stormwater Best Management Practices Manual  
<http://portal.ncdenr.org/web/lr/bmp-manual>

#### 2.1.3 ACKNOWLEDGEMENTS

This division has been prepared by Appian Consulting Engineers, P.A. of Rocky Mount, North Carolina, in cooperation with the Town of Wake Forest, North Carolina. Appian has collected design data from over 10 drainage criteria manuals from throughout the United States. Those manuals were available for use in preparing this division. However, the content of this division is largely derived from the *Drainage Criteria Manual for Montgomery County, Texas*, [Dodson, 1989], and *Elements of Urban Stormwater Design*, [H. Rooney Malcom, P.E., 1989]. These manuals were particularly important because of their format, quality, completeness, and because they represented accepted criteria applied in the area of the Town of Wake Forest.

**2.1.4 DISCLAIMER**

To the best of their ability, the authors of this manual ensured that the material is accurate and reliable for use by others in the development of stormwater management plans and calculations. It is the final responsibility of the design professional to ensure that any methods, procedures and techniques specified in this manual are appropriate for a given situation. The Town of Wake Forest does not accept responsibility for any cost, loss, damage or injury resulting from the use of this manual.

**2.2 STORMWATER MANAGEMENT REVIEW**

A **Stormwater Management Permit** is required for all new development and redevelopment within the Town of Wake Forest jurisdiction, including, but not limited to site plan applications, subdivision applications and grading application, unless exempt per Section 2.2.1. The Town of Wake Forest is a Phase II community, and implements post-construction stormwater management in new development and redevelopment in accordance with the Clean Water Act and Phase II Stormwater Rules. The US Environmental Protection Agency designated the Town for inclusion in the Phase II Stormwater Program because its municipal boundary intersects a US Census-defined Urbanized area.

**2.2.1 EXEMPTIONS**

As noted in the Town of Wake Forest Unified Development Ordinance Section 12.5.1, the following types of development and redevelopment shall be **exempt** from the provisions of this ordinance, provided that they are not in the Falls Lake Watershed and are not part of a large plan of common development or sale:

- A. Development or redevelopment that cumulatively disturbs less than 1 acre;
- B. All development or redevelopment in the RA-HC and UMX Districts;
- C. Redevelopment in all districts with no increase in impervious coverage;
- D. All development or redevelopment of State or Federally owned properties.

**2.2.2 WHEN A PERMIT IS REQUIRED**

Unless excluded by Section 2.2.1, a stormwater management plan and permit is required for land disturbance as follows:

**Table 2.1**

Type of Development	Phase II Rules	Falls Lake Watershed
Single-family, detached and duplex residential	1.0 ac or greater	0.50 ac or greater
Multi-family residential, commercial & industrial	1.0 ac or greater	12,000 sf or greater
Refer to Section:	Section 2.3.1	Section 2.3.2

**2.2.3 NEUSE RIVER BASIN RIPARIAN BUFFER PROTECTION**

All development and redevelopment within the Town jurisdiction shall comply with the standards of the Neuse River Basin: Nutrient Sensitive Waters Management Strategy: Protection and Maintenance of Riparian Areas with Existing Forest Vegetation (15A NCAC 2B.0233), as amended, and the Town of Wake Forest Unified Development Ordinance, Section 12.7.2, "Watercourse Buffer Tables." Any encroachment within a Neuse River riparian buffer, wetland or stream is subject to NCDENR approval. Additional information about the Neuse Nutrient Strategy may be obtained at:

<http://portal.ncdenr.org/web/wq/ps/nps/neuse>.

### 2.2.4 FALL LAKE WATERSHED STANDARDS

Part of the Town is located within the Falls Lake Watershed of the Neuse River Basin. New development within the Falls Lake Watershed must also comply with the Falls Lake Nutrient Strategy (15A NCAC 2B .0275-.0282), discussed in Section 2.3.2. Additional information may be obtained at:

<http://portal.ncdenr.org/web/fallslake>

### 2.2.5 STORMWATER MANAGEMENT PERMIT APPLICATION

The Stormwater Management Permit application package should be inclusive of all necessary materials to understand the design and how the site will be developed in relation to stormwater management. Refer also to Section 6.6, which details plan and submittal requirements.

- A. **Stormwater Permit Application:** Applicants are to submit the latest “State Stormwater Permit Application” forms (including Low Density Supplement Form, if applicable) from NCDENR:  
[http://portal.ncdenr.org/web/lr/state-stormwater-forms\\_docs](http://portal.ncdenr.org/web/lr/state-stormwater-forms_docs)
- B. **Stormwater Management Checklist:** The application must be submitted with the items as detailed in the Stormwater Management Checklist, *Form SW100*, found in Section 2.12 of this manual and online at: <http://www.wakeforestnc.gov>.
- C. Additional checklists and worksheets are included in the NC Department of Environment and Natural Resources (NCDENR) Stormwater Best Management Practices Manual, latest revision, available online at:  
<http://portal.ncdenr.org/web/lr/bmp-manual>.

### 2.2.6 CALCULATION REQUIREMENTS

All storm water calculations (runoff, pipe, ditch and inlet sizing and detention routing (if required)) shall be submitted with the plans.

- A. Calculations shall consider inlet and outlet control, hydraulic grade line and backwater as applicable.
- B. The calculation package shall identify the project name and location, name of designer, and shall bear the designer’s seal, date and signature.
- C. All detention/retention facilities in the jurisdiction of Town of Wake Forest shall be designed to attenuate developed condition peak discharges to the existing conditions for the given storm calculation. See Section 2.8.
- D. All BMPs shall be designed according to the NCDENR Stormwater Best Management Practices Manual, with NCDENR supplement forms submitted in the calculation package. See Section 2.8.

### 2.2.7 PLAN REQUIREMENTS

- A. **Tributary Areas:** Tributary area plans (runoff map) must be included to justify discharges in all cases. Plans shall either show storm drainage calculations or the calculations shall be submitted in a separate package as noted above in Section 2.2.6 above.
- B. **Plan Submittals:** Profiles and cross-sections for existing and proposed drainage courses may be required at the discretion of the Town’s Engineer. When required, plans shall include street and/or off-street profiles of drainage ditches/pipe systems included for public maintenance. Profiles shall be same scale as plan view and shall show any water or sewer crossings or parallel lines.

## 2.3 PHASE II & WATERSHED PROTECTION REQUIREMENTS

Where a stormwater permit is required for projects within the jurisdiction of the Town, projects shall comply with the Phase II program requirements (Section 2.3.1), the supplemental Falls Lake Rules (Section 2.3.2), and Richland Creek and Smith Creek Water Supply Watershed requirements (Section 2.3.3).

### 2.3.1 PHASE II REQUIREMENTS: LOW OR HIGH DENSITY OPTION

In accordance with the Phase II rules all development and redevelopment shall be permitted as either a Low Density or High Density Project. **Note that nutrient calculations are not required unless the project is within the Falls Lake Watershed.**

**Table 2.2**

Stormwater Permit Option	Summary of Requirements
Low Density	<ul style="list-style-type: none"> <li>• 24% or less BUA</li> <li>• Vegetated conveyances (no stormwater collection system)</li> </ul>
High Density	<ul style="list-style-type: none"> <li>• Greater than 24% BUA</li> <li>• 70% BUA max</li> <li>• 85% TSS removal</li> <li>• Post = Pre for 1-year, 24-hour storm</li> </ul>

- A. Low Density** projects shall include those developments that have a maximum of 24% built upon area for all residential and non-residential development; and
1. A maximum density of two (2) dwelling units per acre for single family detached development; OR
  2. A minimum lot size of 20,000 square feet for single family detached development (excluding roadway right-of-way).
  3. Total project area shall include total acreage in the tract on which the project is to be developed.
  4. Low density projects shall comply with each of the following standards:
    - a. **Vegetated Conveyances:** Stormwater runoff shall be transported by vegetated conveyances to the maximum extent practicable.
    - b. **Watercourse Buffers (Minimum Each Side):** See Section 12.7 of the Unified Development Ordinance.
- B. High Density** projects shall include those developments with greater than 24% built upon area for all residential and non-residential development.
1. New residential and non-residential development shall not exceed seventy percent (70%) impervious surface.
  2. For the purpose of calculating the impervious surface area, total project area shall include total acreage in the tract on which the project is to be developed.
  3. High density projects shall comply with each of the following standards:
    - a. **Runoff Volume:** Stormwater control measures shall control and treat the difference in stormwater runoff volume leaving the project between the pre- and post-development conditions for, at a minimum, the *1-year, 24-hour storm*. Runoff volume drawdown time shall be a minimum of 48 hours, but not more than 120 hours.

- b. **Total Suspended Solids (TSS):** All structural stormwater treatment systems used to meet the requirements of the program shall be designed to have a minimum of 85% average annual removal for Total Suspended Solids.
- c. **Design Criteria:** General engineering design criteria for all projects shall be in accordance with 15A NCAC 2H .1008(c), as explained in the NCDENR Stormwater Best Management Practices Manual, available online at: <http://portal.ncdenr.org/web/lr/bmp-manual>
- d. **Watercourse Buffers (Minimum Each Side):** See Section 12.7 of the Unified Development Ordinance.

## 2.3.2 FALLS LAKE WATERSHED REQUIREMENTS

*In addition* to the Low-Density or High-Density requirements described in Section 2.3.1, all development within the Falls Lake Watershed must comply with the Falls Lake Nutrient Strategy (15A NCAC 2B .0275-.0282), with requirements described below. Additional information may be obtained at: <http://portal.ncdenr.org/web/fallslake>.

### A. Nitrogen and Phosphorus Loading

1. Nitrogen and phosphorus loads contributed by the proposed new development shall not exceed the following unit-area mass loading rates: 2.2 and 0.33 pounds per acre per year for nitrogen and phosphorus, respectively.

**Table 2.3**

	Falls Lake Watershed Maximum Limit (lbs/ac/year)
Nitrogen	2.2
Phosphorus	0.33

2. **Falls Nutrient Loading Accounting Tool:** Calculations within the Falls Lake Watershed are to follow the model and worksheets described provided by NCDENR with the nutrient loading limits described above. The developer shall determine the need for engineered stormwater controls to meet these loading rate targets by using the approved accounting tool. The Falls Lake Nutrient Loading Accounting Tool can be found online at: <http://portal.ncdenr.org/web/fallslake/rules-implementation-information>.
3. **Redevelopment Option:** Notwithstanding 15A NCAC 2B.104(q), redevelopment that would replace or expand existing structures or improvements and would result in a net increase in built-upon area shall have the option of either meeting the nutrient loading standards identified above OR meeting a loading rate that achieves the following nutrient loads compared to the existing development: 40% and 77% reduction for nitrogen and phosphorus, respectively.

**B. Nitrogen and Phosphorus Standard is Supplemental:** The nitrogen and phosphorus loading standards in this section are supplemental to, not replacements for, stormwater standards otherwise required by federal, state or local law, including without limitation any riparian buffer requirements applicable to the location of the development, 15A NCAC 2B .0223 and .0242.

**C. Control and Treatment of Runoff Volume:** Stormwater systems shall be designed to control and treat the runoff generated from all surfaces by one inch of rainfall.

1. The treatment volume shall be drawn down pursuant to standards specific to each practice as provided in the NCDENR Stormwater Best Management Practices Manual.
2. To ensure that the integrity and nutrient processing functions of receiving waters and associated riparian buffers are not compromised by erosive flows, stormwater flows from the development shall not contribute to degradation of waters of the State.
3. At a minimum, the development shall not result in a net increase in peak flow leaving the site from pre-development conditions for the 1-year, 24-hour storm event.

**D. Partial Offset of Nutrient Control Requirements:** Development subject to this ordinance shall attain nitrogen and phosphorus loading rate reductions on-site that meet the following criteria prior to using an offsite offset measure:

1. 30% or more reduction in both nitrogen and phosphorus loading from the untreated conditions for any single-family, detached and duplex residential development disturbing  $\frac{1}{2}$  acre but less than 1 acre.
2. 50% or more reduction in both nitrogen and phosphorus loading from the untreated conditions for any single-family, detached and duplex residential development disturbing more than 1 acre.
3. 30% or more reduction in both nitrogen and phosphorus loading from the untreated condition for other development, including multi-family residential, commercial and industrial development disturbing 12,000 square feet but less than 1 acre.
4. 50% or more reduction in both nitrogen and phosphorus loading from the untreated condition for other development, including multi-family residential, commercial and industrial development disturbing more than 1 acre.

**Table 2.4**

<i>Type of Development</i>	<i>Area Disturbed</i>	<i>Minimum Reduction in N&amp;P from Untreated Conditions</i>
Single-family, detached and duplex residential	0.50 ac to 0.99 ac	30%
	1.0 ac or more	50%
Other development, including multi-family residential, commercial and industrial development	12,000 sf to 0.99 ac	30%
	1.0 ac or more	50%

**E. Nutrient Offset Payments:** A developer subject to the Falls Lake nutrient requirements can offset nutrient loading on site or choose a third-party mitigation provider such as the NC Ecosystem Enhancement Program (NCEEP) or a compensatory mitigation bank to “buy down” their loading requirements to meet the thresholds established for nutrient loading. A Developer is required to purchase credits from a **private mitigation bank** unless:

1. There are no listed mitigation banks with nutrient credits located in the hydrologic unit where this impact will take place; see NCDENR link below:  
[http://portal.ncdenr.org/c/document\\_library/get\\_file?uuid=0bd3ee09-a658-468f-bc10-e3a897636ee8&groupId=38364](http://portal.ncdenr.org/c/document_library/get_file?uuid=0bd3ee09-a658-468f-bc10-e3a897636ee8&groupId=38364)  
 OR

2. The applicant is a Federal or State Government Entity or a unit of local government meeting the requirements set forth in G.S. 143-214.11 (as amended by SL 2011-343) and is not required to purchase credits from a mitigation bank; OR
3. There are no credits available from the mitigation bank(s) in the hydrologic unit where the impacts will occur; OR
4. The use of a mitigation bank was not approved to provide the required mitigation for this project (written confirmation from permitting agency required).

**F. NC Ecosystem Enhancement Program's Nutrient Offset Program:**

The NC Ecosystem Enhancement Program's Nutrient Offset Program (NCEEP) was developed to provide a mechanism to assist developers in meeting their nutrient loading requirements. The NCEEP partners with private biological-engineering and mitigation contractors on wetlands restoration and enhancement programs across the state. NCEEP accepts "buy down" payments from permit holders in lieu of actual undertaking of a mitigation project. NCEEP then uses the money to create, restore or enhance wetlands, streams and riparian areas. Refer to:

<http://portal.ncdenr.org/web/ceep/nutrient-offset-request-process>

Questions regarding process may be addressed to:

**Kelly Williams**

**NCEEP In-Lieu Fee Program Coordinator**

919.707.8915/[kelly.williams@ncdenr.gov](mailto:kelly.williams@ncdenr.gov)



### 2.3.3 WATER SUPPLY WATERSHED REQUIREMENTS

Development and redevelopment within the Richland Creek (WS-IV) and Smith Creek (WS-II) Water Supply Watersheds shall comply with the requirements prescribed by NCDENR and the Town of Wake Forest Unified Development Ordinance, Section 12.6. See Table 2.5 below.

**Impervious Surface Averaging** for two noncontiguous parcels shall be allowable as described in the Town of Wake Forest Unified Development Ordinance, Section 12.6.2

Table 2.5

**1. Falls Lake Water Supply Watershed (Class WS-IV)**

Development Type	Location Classification	Maximum Density	Maximum Impervious Surface Coverage
Single Family Residential Development	Critical Area (FL-CA)	1 unit/ 2 acres	6%
	Watershed Management Area (FL-WMA)	1 unit/ acre	12% w/o municipal water & sewer OR 24% with municipal water & sewer
All Other Development	Critical Area (FL-CA)	Follows base zoning	6%
	Watershed Management Area (FL-WMA)	Follows base zoning	12% w/o municipal water & sewer (Low Density Option); 24% with municipal water & sewer (Low Density Option); OR 70% (High Density Option)*

**2. Richland Creek Water Supply Watershed (Class WS-IV)**

Development Type	Location Classification	Maximum Density	Maximum Impervious Surface Coverage
Single Family Residential Development	Critical Area (RC-CA)	2 units/acre	24% (Low Density Option)
		Follows base zoning	50% (High Density Option)*
	Watershed Management Area (RC-WMA)	Follows base zoning	70% (High Density Option)*
All Other Development	Critical Area (RC-CA)	Follows base zoning	24% (Low Density Option)
			50% (High Density Option)*
	Watershed Management Area (RC-WMA)	Follows base zoning	70% (High Density Option)*

**3. Smith Creek Water Supply Watershed (Class WS-II)**

Development Type	Location Classification	Maximum Density	Maximum Impervious Surface Coverage
Single Family Residential Development	Critical Area (SC-CA)	1 unit/ 2 acres	6%
		1 unit/ 2 acres	24% (High Density Option)*
	Watershed Management Area (SC-WMA)	1 unit/ acre	12% (Low Density Option) 30% (High Density Option)*
All Other Development	Critical Area (SC-CA)	Follows base zoning	6%
			24% (High Density Option)*
	Watershed Management Area (SC-WMA)	Follows base zoning	12% (Low Density Option) 30% (High Density Option)*

\* All high impervious surface options require municipal water and sewer service



## 2.4 STORM DRAINAGE DESIGN

The purpose of this section is to provide a guide for the design of storm drainage systems and structures within the jurisdiction of the Town of Wake Forest.

### 2.4.1 MINIMUM DESIGN STANDARDS

All storm drainage systems within the jurisdiction of the Town of Wake Forest shall meet all the requirements of the Town of Wake Forest Manual of Specifications, Standards and Design, latest revision. The following shall be considered to be the minimum standards of design for storm drainage systems within the jurisdiction of the Town of Wake Forest.

### 2.4.2 GENERAL

The design of storm drainage infrastructure within the jurisdiction of the Town of Wake Forest shall be in accordance with the Technical Specifications. The subdivision/development shall provide an adequate drainage system, including necessary open ditches, pipe culverts, drop inlets, bridges, fill-in lots, etc. for the proper drainage of all surface water. The subdivider/developer shall connect to the Wake Forest storm drainage system where available; if not accessible, the subdivider/developer shall provide open drainage ditches necessary to carry the water in a manner approved by the Town's Engineer. The minimum standards of design shall adhere to the following guidelines.

### 2.4.3 POTENTIAL FLOOD HAZARDS

All subdivisions/development proposals shall be consistent with the need to minimize flood damage. All subdivision/development proposals shall have public utilities and facilities (such as sewer, gas, electrical and water systems) located and constructed to minimize flood damage. All subdivisions/developments shall have adequate drainage provided to reduce exposure to flood hazards.

- A. Evaluation of Downstream Impacts: Unless specifically exempted by the Town's Engineer, all new development shall evaluate the stormwater impacts, created by their project, to off-site existing stormwater systems that receive runoff from the new development. These off-site systems may be open ditches, streams or pipe.
  - 1. The limits of the analysis shall be 500 feet downstream and to a point where the proposed development is 10% of the total watershed.
  - 2. Analysis shall also be conducted upstream to ensure the proposed development does not use up all the existing capacity of the off-site system.
  - 3. If the existing stormwater system(s) cannot handle the runoff from the proposed development, the development shall either:
    - a. Install on site stormwater controls (BMP's) to reduce the peak flow; or
    - b. Upgrade the existing stormwater system to handle the increased flow.
  - 4. All engineered stormwater solutions shall be evaluated by the Town's Engineer to determine whether the improvements meet the Town requirements.

### 2.4.4 DESIGN STORM FREQUENCY

All drainage systems components within the Town of Wake Forest's jurisdiction shall be designed to accommodate the frequency storm per Table 2.6:

**Table 2.6 Design and Check Storms**

Arterial Roadways	25-year	100-year
Collector streets	25-year	100-year
Local Roadways	10-year	25-year
Bridges/Box Culverts, Stream Crossings <sup>1</sup>	50-year	100-year
Open channels <sup>2</sup>	25-year	100-year
Cross-drainage	25-year	-
Adjacent to building structures w/ flooding potential	100-year	-
BMP Structures/Non-structures	Per NCDENR BMP Design Manual	
Drainage facilities for residential development accepting lot runoff only (no roadway discharge)	2-year	10-year
Drainage Facilities providing diffuse flow	10-year	25-year
Drainage Facilities for Parking Lot	10-year	25-year
Spillway structure for impoundment (i.e. detention/retention facilities)	25-year	100-year
Curb & gutters, curb & gutter inlets	2-year, 5 minute TC	-

<sup>1</sup>For regulatory Floodways, the Design Storm is the 100-year return period

<sup>2</sup>See also section 2.6.1

#### 2.4.5 DESIGN METHOD FOR COMPUTING RUNOFF

Storm water runoff calculations shall be computed by the following methods based on the watershed under study:

**Table 2.7**

Watershed	Method
Less than 50 acres	Rational Method
50 to 640 Acres	SCS and Malcom Method
Larger than 640 Acres with multiple sub-areas	HEC 1

#### 2.4.6 DRAINAGE DESIGN CONSTRAINTS

- A. **Velocity:** Velocity of drainage flow after development shall not exceed that before development upon leaving the development.
- B. **Erosion Control:** The Town of Wake Forest has been delegated as an authority to review and approve erosion control plans by the State. All erosion control plans must be submitted to the Town of Wake Forest for review and approval. Erosion control measures shall be in accordance with the North Carolina Erosion Control Manual, latest revision.
- C. **Buffer Strip along natural drainage ways:** All Neuse River Buffer rules must be followed.
- D. **Roadside ditch liners:** In all subdivisions where there is no curb and gutter, side ditches requiring protection shall be concrete paved. Riprap may be accepted upon approval of Town of Wake Forest Engineering staff. See Table 2.19.
- E. **Drainage along subdivision side lot lines:** Storm drainage systems shall follow the natural contour of the subdivision lots.
- F. **Standard improved ditch cross-section:** All improved ditches shall have:
  1. A minimum 3-foot bottom width,

2. A maximum side slope of 3:1.
3. A minimum longitudinal grade of 0.3%.

**G. Rip Rap Filter:** Geotextile fabric will be required under all riprap. Fabric shall meet the requirements of Specification Section 02210, paragraph 2.2.1 Geotextile Fabric. Filter stone may not be used in lieu of fabric.

**H. Limits of Public Ownership and Maintenance Responsibility**

1. All drainage easements shall be public to the end of any storm drainage pipe system stilling basin. **All drainage beyond that point shall be carried in drainage easements which are private and will be owned and maintained by the individual property Owner.**
2. **The Town of Wake Forest assumes no liability or responsibility for adjudicating disputes between property owners regarding non-publicly generated storm water.**
3. **Drainage easements and dedications:** This shall apply both inside the corporate limits and the ETJ as well as in any development receiving Town water and /or sewer service by contract.

Where a subdivision/development is traversed by a water course, drainage way, underground storm drain, the subdivider/developer shall dedicate to the Town (where applicable in accordance with the above) a drainage maintenance easement as specified by Section 6.10.1 of the Town of Wake Forest Unified Development Ordinance. Private drainage easement widths shall also correspond to these same criteria. The Town's Engineer may require wider easement widths if the topography along the proposed right-of-way is such that maintenance equipment cannot reasonably be operated within the easement.

- I. Pipe Material:** All storm drainage pipes shall be reinforced concrete class III minimum B or C Wall. Pipe systems greater than 72-inches in diameter will be reviewed on a case-by-case basis for material and construction.
- J. Manhole rings and covers:** All storm sewer manhole rings and covers shall be sanitary sewer standard, except that they shall be stamped "storm sewer."
- K. Street Pipe Culverts:** Culverts shall be provided to accommodate all natural water flow and shall be of sufficient length to permit full width roadway construction with the required slopes (fill or cut). The pipe shall be designed in accordance with the Stormwater Management and Design Criteria in this chapter. Cross drains shall be built on straight line and grade and shall be laid with the ends filled and matched to provide joints in conformity with Section 2.4.9.L with a smooth invert. They shall be placed at sufficient depth below the roadbed to avoid the dangerous pressure of impact. See Standard Detail 2.53 for installation type, bedding and cover requirements for rigid pipe. However, in a case where the pipe is not more than 12-inches below the roadbed, the pipe shall be reinforced with concrete. The minimum diameter is 15 inches (See Section 2.10).
- L. Open Joints in Drainage Pipe:** Where it is deemed necessary by the Town's Engineer, the joint in the bottom 2-inches (of the pipe diameter) shall be left open to permit groundwater infiltration into the pipe system. The pipe shall have bedding conforming to Standard Detail 2.53 as well as Technical Specification Section 02700 paragraph 3.3.B Bedding Rigid Pipe.
- M. Road/Street Foundation Subdrain/Underdrain:** A subdrain will be required in all cases where high water tables may cause problems with subgrade. Parallel or herringbone systems will be used as appropriate.

- N. Precast Catch Basins:** Precast catch basins with weep holes shall generally be required. See standard Details 2.50 through 2.61 as applicable.
- O. Flared End Sections:** Flared end sections will be permitted on pipe as follows:
  1. On single pipe systems up to a 42" diameter
  2. On twin pipe systems up to 18" diameter.

Otherwise, head walls will be used for all larger pipe systems and for all other multi-barrel pipe systems.
- P. Head/End walls:** For Head/End wall construction details, refer to the NCDOT Highway Design Branch Roadway Standard Drawings, latest revision. Standard Drawings are to be used *in conjunction* with the NCDOT Standard Specifications unless otherwise more restrictive as specified in this manual.
- Q. Combined Sewer Flow:** No storm water drainage shall be discharged into a sanitary sewer.

## 2.5 HYDROLOGIC ANALYSIS: DETERMINATION OF RUNOFF

The purpose of this section is to establish standard procedures and criteria for the performance of hydrologic analyses in the Town of Wake Forest.

### 2.5.1 DETERMINATION OF RUNOFF

- A.** The determination of runoff may be the single most important factor in the planning, design, and construction of drainage facilities. If the estimate of storm runoff is incorrect, the constructed facilities may be undersized or oversized. An improperly designed drainage system may be uneconomical, cause flooding, interfere with traffic, and may be a general nuisance in the affected area. However, determination of runoff can only be approximated using sound engineering processes to represent physical and climatic factors to best model the system.
- B.** There are many methods currently available to estimate peak flow rates. The Town of Wake Forest will use the Rational Method for watersheds smaller than 50 acres, the SCS and the Malcom Method to develop runoff hydrographs for watersheds greater or equal to 50 acres and less than 640 acres, and HEC 1 for watersheds greater than 640 acres and for watersheds with multiple sub-areas.

### 2.5.2 WATERSHEDS SMALLER THAN 50 ACRES: RATIONAL METHOD

For small drainage areas (less than 50 acres in size), the widely used Rational Method provides a useful means of determining peak discharges. The Rational Method represents an accepted method for determining peak storm runoff rates for small watersheds that have a drainage system unaffected by complex hydrologic situations such as ponding areas and storage basins.

- A.** It is generally recommended that in the Town of Wake Forest that Rational Method be used for areas of less than 50 acres.
- B.** In situations requiring determination of a complete flood hydrograph, and not just a peak discharge, a method developed by H.R. Malcom [Malcom, Updated] should be utilized. Engineers wishing to use an alternative design technique should consult the Town's Engineer prior to design.
- C. Rainfall Intensity:** Point precipitation estimates shown in Table 2.8 for the Town of Wake Forest were obtained from NOAA's National Weather Service Hydrometeorological Design Studies Center and are based on the latest rainfall data as of this printing. Since rainfall estimates are based on continuously changing

statistical data, the designer is encouraged to verify the latest rainfall data from NOAA's National Weather Service Hydrometeorological Design Studies Center online at: [http://hdsc.nws.noaa.gov/hdsc/pfds/pfds\\_map\\_cont.html?bkmrk=nc](http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc).

### 2.5.3 WATERSHEDS FROM 50 TO 640 ACRES: SCS AND MALCOM'S METHOD

- A. Hydrological analyses involving watersheds of greater than or equal to 50 acres and less than 640 acres may be completed using the SCS and Malcom Method to develop runoff hydrographs.
- B. Malcom's Method for hydrograph development is useful in the design of facilities which require an analysis over time. This procedure can be used in conjunction with the Soil Conservation Service (SCS) Method or the Rational Method. This methodology utilizes a pattern hydrograph to obtain a curvilinear design hydrograph which peaks at the design flow rate and which contains a runoff volume consistent with the design rainfall. The pattern hydrograph is a step function approximation to the dimensionless hydrograph proposed by the Bureau of Reclamation and the Soil Conservation Service [SCS, 1972].
- C. This method is commonly used in designs that require storage areas, detention/retention basin design, ponding areas, or simply when a system needs to be routed in order to determine a peak elevation for any given storm event.

### 2.5.4 WATERSHEDS LARGER THAN 640 ACRES

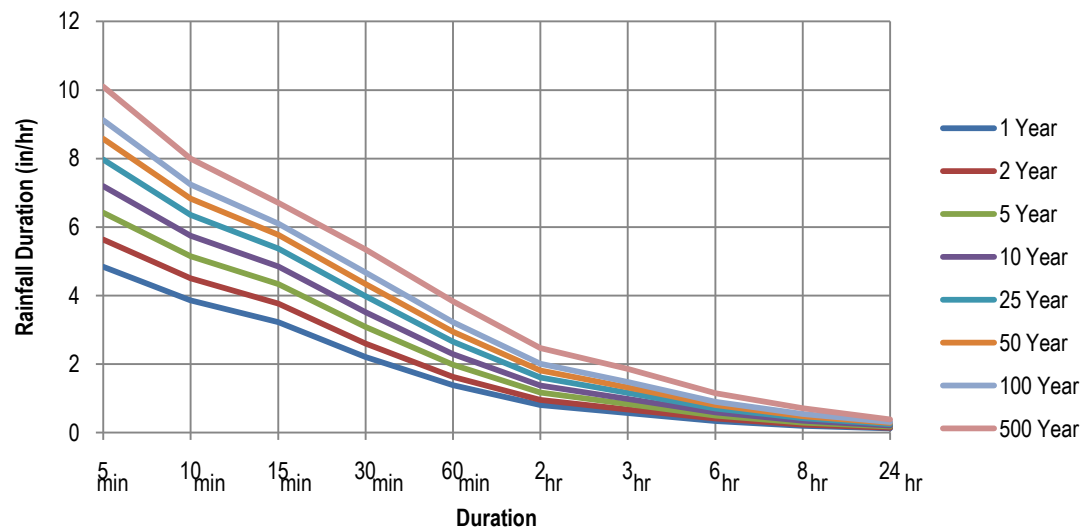
For areas less than 2,000 acres, the SCS Tabular or Synthetic Hydrograph or Snyder's Synthetic Unit Hydrograph (Hydrain includes this design alternate. See HEC 19 [archived] for detailed direction in this procedure.) method may be used for determining volume of flow and peak discharge. HEC 1 may also be used for basin areas larger than 640 acres (1 sq. mi.). Hydrograph methods can be computationally involved so computer programs such as HEC 1, TR-20, TR-55, and HYDRAIN may be utilized.

### 2.5.5 DESIGN AIDS

The following tables and figures provide information for stormwater management design.

**Figure 2.1**  
**I-D-F Curve**

Town of Wake Forest



Source: Point Precipitation Frequency Estimates from NOAA Atlas 14, Vol. 2, Ver. 3  
Wake Forest, North Carolina, 35.9768, -78.5108

**Table 2.8 Rainfall Intensity-Duration-Frequency Table for the Town of Wake Forest**

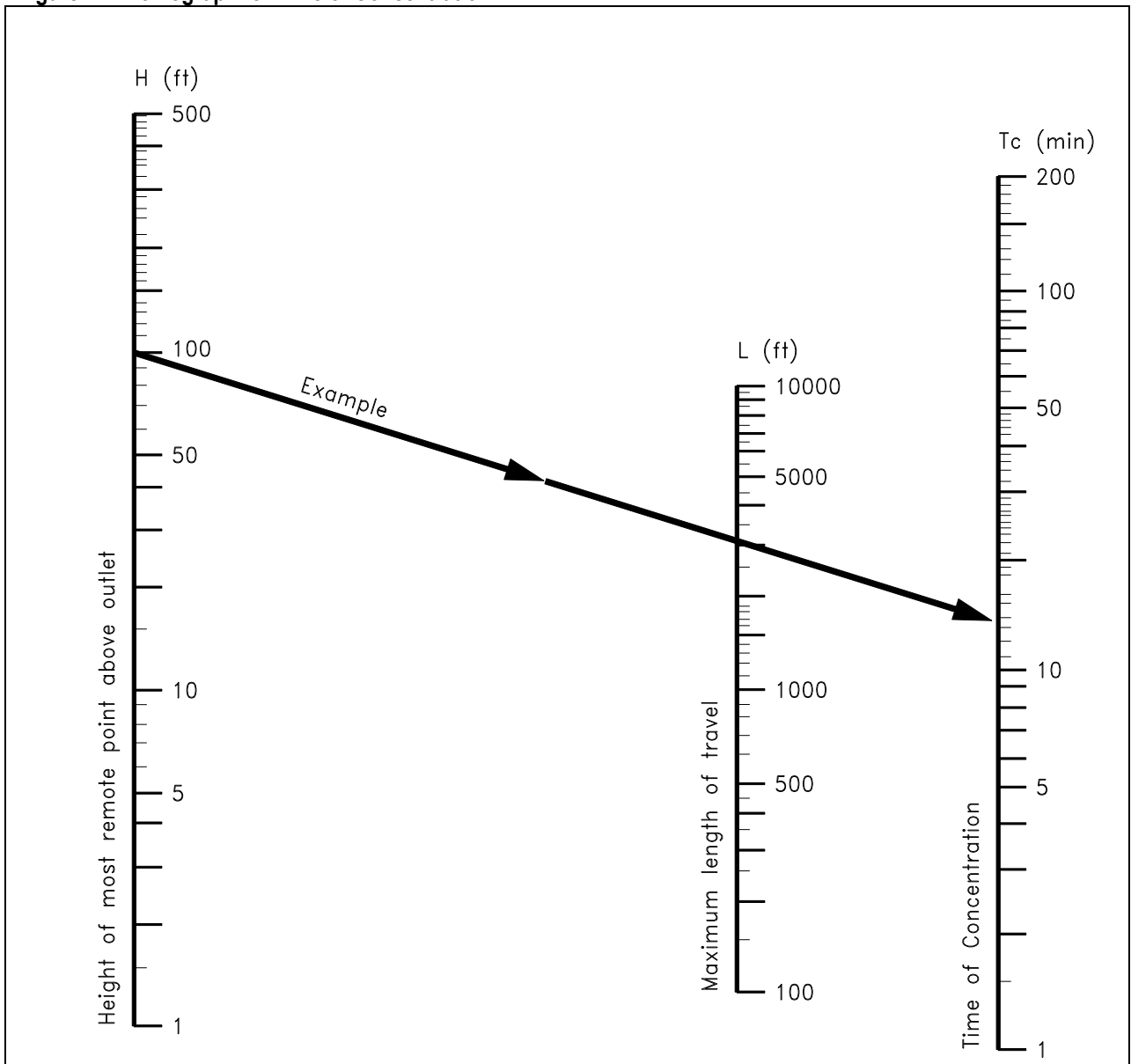
Return Period →								
Duration	1 year (in/hr)	2 year (in/hr)	5 year (in/hr)	10 year (in/hr)	25 year (in/hr)	50 year (in/hr)	100 year (in/hr)	500 year (in/hr)
5 minute	4.84	5.63	6.42	7.19	7.97	8.58	9.12	10.1
10 minute	3.86	4.50	5.15	5.75	6.35	6.83	7.24	8.00
15 minute	3.22	3.77	4.34	4.85	5.37	5.77	6.10	6.71
30 minute	2.21	2.60	3.08	3.51	3.98	4.34	4.67	5.34
60 minute	1.38	1.63	1.98	2.29	2.65	2.94	3.22	3.83
2 hour	0.804	0.958	1.17	1.37	1.61	1.81	2.01	2.47
3 hour	0.568	0.678	0.831	0.979	1.16	1.32	1.48	1.86
6 hour	0.342	0.408	0.501	0.591	0.703	0.803	0.902	1.15
12 hour	0.201	0.239	0.295	0.350	0.420	0.482	0.546	0.707
24 hour	0.119	0.144	0.180	0.209	0.248	0.279	0.310	0.387

Point Precipitation Frequency Estimates from NOAA Atlas 14, Vol. 2, Ver. 3  
Wake Forest, North Carolina, 35.9768, -78.5108

**Table 2.9 Depth-Duration-Frequency Table for the Town of Wake Forest**

Duration	Return Period →							
	1 year (in)	2 year (in)	5 year (in)	10 year (in)	25 year (in)	50 year (in)	100 year (in)	500 year (in)
5 minute	0.403	0.469	0.535	0.599	0.664	0.715	0.760	0.843
10 minute	0.644	0.750	0.858	0.959	1.06	1.14	1.21	1.33
15 minute	0.804	0.942	1.08	1.21	1.34	1.44	1.53	1.68
30 minute	1.10	1.30	1.54	1.76	1.99	2.17	2.34	2.67
60 minute	1.38	1.63	1.98	2.29	2.65	2.94	3.22	3.83
2 hour	1.61	1.92	2.34	2.74	3.21	3.63	4.02	4.93
3 hour	1.71	2.04	2.50	2.94	3.48	3.96	4.43	5.58
6 hour	2.05	2.44	3.00	3.54	4.21	4.81	5.40	6.87
12 hour	2.42	2.88	3.56	4.22	5.06	5.81	6.58	8.52
24 hour	2.86	3.45	4.33	5.02	5.95	6.69	7.44	9.28

Point Precipitation Frequency Estimates from NOAA Atlas 14, Vol. 2, Ver. 3  
Wake Forest, North Carolina, 35.9768, -78.5108

**Figure 2.2 Nomograph for Time of Concentration**

Source: "E & S Control Planning and Design Manual," [DEHNR, May 1994 Revised]

**Notes:**

1. Use nomograph  $t_c$  for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.
2. For overland flow, grassed surfaces, multiply  $t_c$  by 2.
3. For overland flow, concrete or asphalt surfaces, multiply  $t_c$  by 0.4.
4. For concrete channels, multiply  $t_c$  by 0.2.

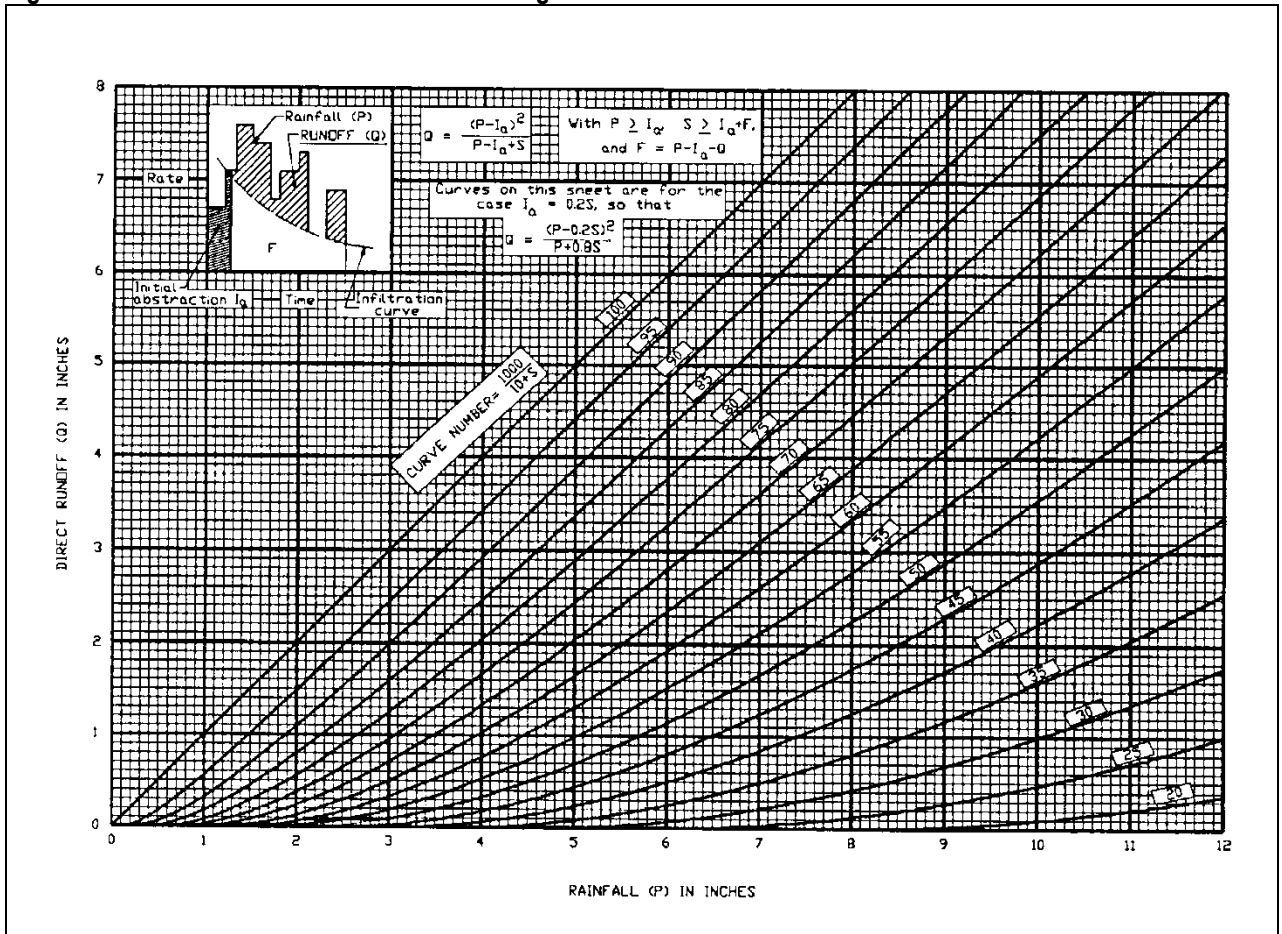


**Table 2.10 Rational Method Runoff Coefficients for 5 – 10 Year Frequency Storms**

Description of Area	Basin Slope < 1%	Basin Slope 1% - 3.5%	Basin Slope 3.5% - 5.5%
Single Family Residential Districts			
Lots greater than ½ acre	0.30	0.35	0.40
Lots ¼ - ½ acre	0.40	0.45	0.50
Lots less than ¼ acre	0.50	0.55	0.60
Multi-Family Residential Districts	0.60	0.65	0.70
Apartment Dwelling Areas	0.75	0.80	0.85
Business Districts			
Downtown	0.85	0.87	0.90
Neighborhood	0.75	0.80	0.85
Industrial Districts			
Light	0.50	0.65	0.80
Heavy	0.60	0.75	0.90
Railroad Yard Areas	0.20	0.30	0.40
Cemeteries	0.10	0.18	0.25
Playgrounds	0.20	0.28	0.35
Streets			
Asphalt	0.80	0.80	0.80
Concrete	0.85	0.85	0.85
Concrete Drives and Walks	0.85	0.85	0.85
Roofs	0.85	0.85	0.85
Lawn Areas			
Sandy Soil	0.05	0.08	0.12
Clay Soil	0.15	0.18	0.22
Woodlands			
Sandy Soil	0.15	0.18	0.25
Clay Soil	0.18	0.20	0.30
Pasture			
Sandy Soil	0.25	0.35	0.40
Clay Soil	0.30	0.40	0.50
Cultivated			
Sandy Soil	0.30	0.55	0.70
Clay Soil	0.35	0.60	0.80
Bare Soil			
Sandy Soil	0.40	0.50	0.60
Clay Soil	0.60	0.70	0.80
Pond and Lakes	0.98	0.98	0.98

Source: "Drainage Criteria Manual For Montgomery County, Texas," 1989, revised ACE 1998.

Figure 2.3 Determination of Runoff Volume Using SCS Curve Number



Source: "Drainage Criteria Manual for Montgomery County Texas," [Dodson, 1989]

**Table 2.11 Values of SCS Curve Number for Urban and Suburban Areas**

Land Use Description	Hydrologic Soil Group			
	A	B	C	D
<b>Residential</b>				
1/8 acre or less average lots (65% impervious)	77	85	90	92
1/4 acre average lots (38% impervious)	61	75	83	87
1/3 acre average lots (35% impervious)	57	72	81	86
1/2 acre average lots (25% impervious)	54	70	80	85
1 acre average lots (20% impervious)	51	68	79	84
Paved parking lots, roofs, driveways, etc.	98	98	98	98
<b>Streets and Roads</b>				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
<b>Commercial &amp; Business Areas (85% impervious)</b>	89	92	94	95
<b>Industrial Districts (72% Impervious)</b>	81	88	91	93
<b>Open Spaces, Lawns, Parks, Golf Courses, Cemeteries, etc.</b>				
Good condition: grass cover on 75% or more	39	61	74	80
Fair condition: grass cover on 50% to 75%	49	69	79	84
Fallow/Straight Row	77	86	91	94
<b>Row Crops</b>				
Straight Row, Poor Condition	72	81	88	91
Straight Row, Good Condition	67	78	85	89
Contoured, Poor Condition	70	79	84	88
Contoured, Good Condition	65	75	82	86
Contoured and Terraced, Poor Condition	66	74	80	82
Contoured and Terraced, Good Condition	62	71	78	81
<b>Small Grain</b>				
Straight Row, Poor Condition	65	76	84	88
Straight Row, Good Condition	63	75	83	87
Contoured, Poor Condition	63	74	82	85
Contoured, Good Condition	61	73	81	84
Contoured and Terraced, Poor Condition	61	72	79	82
Contoured and Terraced, Good Condition	59	70	78	81
<b>Close-Seeded Legumes or Rotation Meadow</b>				
Straight Row, Poor Condition	66	77	85	89
Straight Row, Good Condition	58	72	81	85
Contoured, Poor Condition	64	75	83	85
Contoured, Good Condition	55	69	78	83
Contoured and Terraced, Poor Condition	63	73	80	83
Contoured and Terraced, Good Condition	51	67	76	80
<b>Pasture or Range</b>				
Poor Condition	68	79	86	89
Fair Condition	49	69	79	84
Good Condition	39	61	74	80
Contoured, Poor Condition	47	67	81	88
Contoured, Fair Condition	25	59	75	83
Contoured, Good Condition	6	35	70	79
<b>Meadow, Good Condition</b>	30	58	71	78
<b>Woods or Forest Land</b>				
Poor Condition	45	66	77	83
Fair Condition	36	60	73	79
Good Condition	25	55	70	77
<b>Farmsteads</b>	59	74	82	86

Source: [McCuen, 1982]

## 2.6 OPEN CHANNEL DESIGN

The purpose of this section is to establish standard procedures and criteria for Open Channel Design for the Town of Wake Forest.

### 2.6.1 INTRODUCTION

Open channels, where allowed, shall be designed for the peak runoff produced by a 10-year frequency storm where duration equals time of concentration but no less than 5 minutes. Where applicable, an analysis shall also be provided for the 25-year/24 hour frequency storm, i.e. roadway overtopping, and for the 100-year /24 hour frequency storm, i.e. adjacent building structures. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off-site areas, assuming ultimate development in accordance with the current zoning regulations and the Land Use Plan.

Also see Section 2.6.3.

### 2.6.2 THE MANNING EQUATION

- A. The Manning equation is an empirical relationship which relates friction slope, flow depth, channel roughness, and channel cross-sectional shape to flow rate. The **friction slope** is a measure of the rate at which energy is being lost due to channel resistance. When the channel slope and the friction slope are equal ( $S_f = S_o$ ), the flow is uniform and the Manning equation may be used to determine the depth for uniform flow, commonly known as the **normal depth**.

The Manning equation is as follows:

$$V = \left( \frac{1.49}{n} \right) R^{2/3} \sqrt{S_f} \quad \text{(Equation 2.1)}$$

or

$$Q = \left( \frac{1.49}{n} \right) A R^{2/3} \sqrt{S_f} \quad \text{(Equation 2.2)}$$

Where,

- $Q \rightarrow$  Total discharge (cfs)
- $V \rightarrow$  Velocity of flow (ft/sec)
- $n \rightarrow$  Manning coefficient of roughness (dimensionless), an experimentally determined value which is a function of the nature of the channel lining (Section 2.6.2.B).
- $A \rightarrow$  Cross-sectional area of the flow (ft<sup>2</sup>)
- $R \rightarrow$  Hydraulic radius of the channel (ft) (flow area/wetted perimeter). Wetted perimeter is the distance along the perimeter of the cross section against which water is flowing. It DOES NOT include the free water surface (Section 2.6.3.G).
- $S_f \rightarrow$  Friction slope, the rate at which energy is lost due to channel resistance. Longitudinal slope of the water surface (feet fall/feet run). If flow is uniform, it is also the slope of the invert of the channel.

The area ( $A$ ) and the hydraulic radius ( $R$ ) are written in terms of the depth ( $y_o$ ). Knowing the discharge ( $Q$ ), Manning “ $n$ ” value, and the channel slope ( $S_o$ ), Equation 2.20 can be solved by trial to find normal depth ( $y_o$ ).

### B. Manning 'n' Values

The Manning “ $n$ ” value is an experimentally derived constant which represents the effect of channel roughness in the Manning equation. Considerable care must be given to the selection of an appropriate “ $n$ ” value for a given channel due to its significant effect on the results of the Manning equation. Tables 2.12 through 2.16 provide a listing of “ $n$ ” values for various channel conditions.

**Table 2.12 Manning Roughness Coefficient for Excavated or Dredged Channels**

Type of Channel and Description	Minimum	Normal	Maximum
Earth, straight and uniform			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.019	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
Earth, winding and sluggish			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
Dragline-excavated or dredged			
No vegetation	0.025	0.028	0.033
Light brush or banks	0.035	0.050	0.060
Rock cuts			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
Channels not maintained and brush uncut			
Dense weeds, high as flow depth	0.050	0.080	0.112
Clean bottom, brush on sides	0.040	0.050	0.080
Same, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140

Source: [Chow, 1959]

**Table 2.13 Manning Roughness Coefficient for Lined or Built-Up Channels**

Type of Channel and Description	Minimum	Normal	Maximum
Metal			
Unpainted Smooth steel surface	0.011	0.012	0.014
Painted smooth steel surface	0.012	0.013	0.017
Corrugated metal	0.021	0.025	0.030
Cement			
Neat, surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
Wood			
Planed, untreated	0.010	0.012	0.014
Planed, creosoted	0.011	0.012	0.015
Unplaned	0.011	0.013	0.015

Wood plank with battens	0.012	0.015	0.018
Concrete			
Trowel finish	0.011	0.013	0.015
Float finish	0.013	0.015	0.016
Finished, with gravel on bottom	0.015	0.017	0.020
Unfinished	0.014	0.017	0.020
Concrete on good excavated rock	0.018	0.020	---
Concrete on irregular excavated rock	0.022	0.027	---
Gravel bottom			
sides of Formed concrete	0.017	0.020	0.025
sides of Random stone in mortar	0.020	0.023	0.026
sides of Dry rubble or rip-rap	0.023	0.033	0.036
Brick			
Glazed	0.011	0.013	0.015
in cement mortar	0.012	0.015	0.018
Asphalt			
Smooth	0.013	0.013	---
Rough	0.016	0.016	---
Vegetated lining	0.030	---	0.500

Source: [Chow, 1959]

**Table 2.14 Manning Roughness Coefficient for Minor Natural Streams**

Type of Channel and Description	Minimum	Normal	Maximum
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but some stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of, timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070

Source: [Chow, 1959]

Note: A "minor stream" is one which has a top width of less than 100 feet at flood stage.

**Table 2.15 Manning Roughness Coefficient for Major Natural Streams**

Type of Channel and Description	Minimum	Normal	Maximum
Regular section with no boulders or brush	0.025	---	0.060
Irregular and rough section	0.035	---	0.100

Source: [Chow, 1959]

Note: A "major stream" is one with a top width of more than 100 feet at flood stage. The *n*-value is less than that for minor streams of similar description because banks offer less effective resistance.

**Table 2.16 Manning Roughness Coefficient for Flood Plains**

Type of Channel and Description	Minimum	Normal	Maximum
---------------------------------	---------	--------	---------

Pasture, no brush			
Short grass	0.025	0.030	0.035
High grass	0.030	0.035	0.050
Cultivated areas			
No crop	0.020	0.030	0.040
Mature row crops	0.025	0.035	0.045
Mature field crops	0.030	0.040	0.050
Brush			
Scattered brush, heavy weeds	0.035	0.050	0.070
Light brush and trees, in winter	0.035	0.050	0.060
Light brush and trees, in summer	0.040	0.060	0.080
Medium to dense brush, in winter	0.045	0.070	0.110
Medium to dense brush, in summer	0.070	0.100	0.160
Trees			
Dense willows, summer, straight	0.110	0.150	0.200
Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
Same as above, w/ heavy growth of sprouts	0.050	0.060	0.080
Heavy stand of timber, a few down trees, little undergrowth, flood-stage below branches	0.080	0.100	0.120
Same as above, w/ flood stage reaching branches	0.100	0.120	0.160

Source: [Chow, 1959]

### 2.6.3 OPEN CHANNEL DESIGN

The proper hydraulic design of a channel is of primary importance in ensuring that flooding, sedimentation and erosion problems do not occur. The following general criteria should be used in the design of open channels:

- A. Design Criteria:** The design criteria for storm drainage shall be based upon the data prepared by NC Department of Transportation Guidelines for Drainage Structures, latest revision, USDOT Federal Highway Administration Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, the NC Erosion and Sediment Control Planning and Design, latest revision, the NCDENR Stormwater Best Management Practices Manual, the SCS National Engineering Field Manual for Conservation Practices, or other acceptable calculation procedures. Designers may refer to:

<https://connect.ncdot.gov/resources/hydro/Pages/default.aspx>  
<http://portal.ncdenr.org/web/lr/publications>  
<http://portal.ncdenr.org/web/lr/bmp-manual>.

#### B. Design Frequencies for Open Channel Design

1. All open channels in the Town of Wake Forest shall be designed to contain the runoff from 10 year frequency storm. In addition, the channel must be designed to have sufficient freeboard to provide for adequate drainage of lateral storm sewers during the 25-year/24-hour storm and in some cases even the 100-year/24-hour frequency storm. For example, when a newly designed open channel is being constructed between two existing structures or adjacent to an existing structure, then the channel section must be evaluated using the 100-year/24-hour frequency storm. This will ensure that the existing structures are not flooded frequently. In a naturalized area where the newly constructed channel ties into a natural stream or creek, then the channel is to be evaluated using the 25-year frequency storm.

See also Table 2.6, Design and Check Storms.

2. In those cases where channel modifications are necessary to control increased flow from proposed development, proposed water surface profiles are

restricted such that the 100-year flood profile under existing conditions shall not be increased. If the capacity of the existing channel downstream of the project is less than the 100-year design discharge, consideration shall be given for more frequent events to ensure that the severity and frequency of downstream flooding are not increased.

### C. Required Documentation for Open Channel Designs

The following information must be submitted to the Town of Wake Forest for the design of open channels, but is not limited to the following:

1. **Vicinity Map:** A vicinity map of the site and subject reach.
2. **Site Map:** A detailed map of the area and subject reach.
3. **Watershed Map:** A watershed map showing existing and proposed drainage area boundaries along with all sub-area delineations and all areas of existing or proposed development.
4. **Discharge Calculations:** Discharge calculations specifying the methodology and key assumptions used, along with computed discharges at key locations. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off site areas, assuming ultimate development in accordance with the current zoning regulations and the Unified Development Ordinance.
5. **Hydraulic Calculations:** Hydraulic calculations specifying the methodology used. All assumptions and values of design parameters must be clearly stated.
6. **Plotted Cross-Sections:** Typical existing and proposed cross-sections.

### D. Channel Flow Velocities

Excessive flow velocities in open channels can cause erosion and destabilize side slopes, and may pose a threat to safety. Velocities which are too low may allow the deposition of sediment and subsequent channel clogging. Table 2.17 provides desirable average and maximum allowable velocities based on 10-year flow rates.

**Table 2.17 Allowable Flow Velocities for Channel Design**

Channel Description	Average Velocity (Feet Per Second)	Maximum Velocity (Feet Per Second)
Grass Lined: Predominantly Clay Soils	3.0	4.0
Grass Lined: Predominantly Sand Soils	2.0	4.0
Rip-Rap Lined	5.0	8.0
Concrete Lined	6.0	10.0

- E. **Channel Flow-Line Slope:** Slope of the channel flow-line (invert) is generally governed by topography and the energy head required for flow. Since flow-line slope directly affects channel velocities, channels should have sufficient grade to prevent significant siltation. However, slopes should not be so large as to create erosion problems. In the Town of Wake Forest, the minimum recommended longitudinal slope shall be 0.5 percent (0.005). The use of flatter slopes must be approved by the Town's Engineer. The maximum channel invert slope will be limited by the maximum flow velocities given in Table 2.17. Appropriate channel drop structures may be used to limit channel invert slopes in steep areas.
- F. **Channel Side Slope:** In grass-lined channels, the normal maximum side slope will be 3 horizontal to 1 vertical (3:1), which is the practical limit for mowing

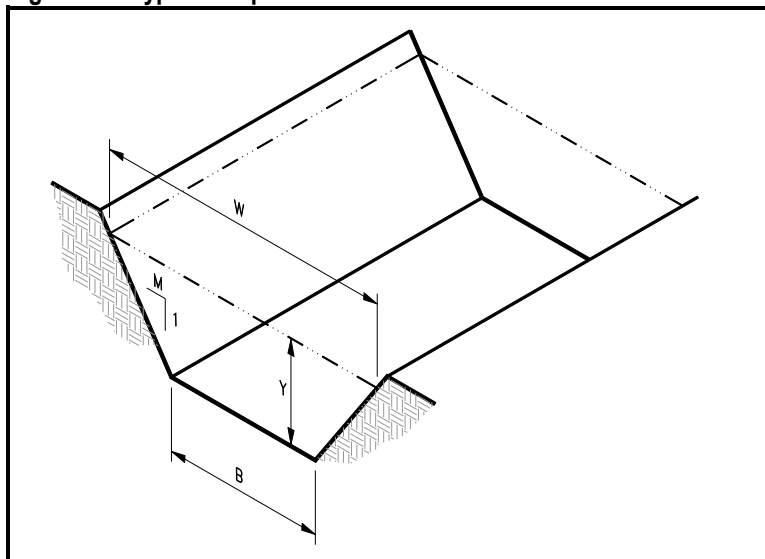


equipment. In some areas, local soil conditions may dictate the use of side slopes flatter than 3:1 to ensure slope stability.

**G. Channel Bottom Width:** In grass-lined channels, the minimum channel bottom width shall be three (3) feet. In concrete-lined channels, the minimum bottom width shall be two (2) feet.

**H. Trapezoidal Channel Design:** In trapezoidal design applications, Figure 2.4 and Equations 2.3 through 2.6 help define the variables used to solve the Manning equation.

**Figure 2.4 Typical Trapezoidal Channel**



Where,

$W \rightarrow$  Top width of flow, measured in feet.

$B \rightarrow$  Bottom width of the channel, measured in feet.

$y \rightarrow$  Depth of flow, measured in feet.

$M \rightarrow$  Side slope ratio (ft. horizontal / ft. vertical).

(For a 2 to 1 side slope, the value of  $M$  is 2.)

$P \rightarrow$  Represents the wetted perimeter.

The following equations are derived geometrically, and the units of the variables are consistent with those given above:

$$A = By + My^2 \quad \text{(Equation 2.3)}$$

$$P = B + 2y\sqrt{1 + M^2} \quad \text{(Equation 2.4)}$$

$$W = B + 2My \quad \text{(Equation 2.5)}$$

$$R = \frac{A}{P} \quad \text{(Equation 2.6)}$$

- I. Manning Roughness Coefficient – Improved Channels:** The values of the Manning roughness coefficient listed in Table 2.18 should be used in the design of channel improvements. Alternative values should be discussed with the Town’s Engineer.

**Table 2.18 Manning Roughness Coefficient for Improved Channels**

Channel Cover	“n” Value
Bare Soil	0.025
Grass-Lined	0.040
Rip-Rap Lined	0.070
Concrete Lined	0.013

#### 2.6.4 CHANNEL PROTECTION

- A.** Erosion protection is necessary to ensure that channels maintain their capacity and stability and to avoid excessive transport and deposition of eroded material.
- B. Drainage Ways**
1. Development shall adequately protect all ditches and drainage ways to the satisfaction of the Town, as noted in Section 2.4.6.D. Ditches and open channels shall be stabilized, seeded, and mulched, sodded or armored, depending on grades and types of soils. As a general rule, ditches and channels, when permitted, shall be lined a follows:

**Table 2.19 Ditch Liners**

Slope	Liner
up to 1%	Seeded, mulched and tacked
1% to 4%	Turf Reinforcement
over 4%	Concrete/Gabions/Other Approved Armored Liners

2. Seeding, sodding, and armoring operations shall be in compliance with the NCDOT Standard specifications for Roads and Structures, latest edition. It is not sufficient to have merely planted according to these specifications; there must be a good stand of permanent grass maintained to meet this requirement. Calculations shall be made to determine the need for riprap outlet protection at pipe outlets.
- C. Easements:** The watercourse or ditch easement shall be wide enough to contain said ditch with ample clearance for the operation of maintenance equipment. The minimum easement width shall be per Section 6.10.1 of the Town of Wake Forest Unified Development Ordinance (UDO), Appendix B.
- D. Downstream Protection:** Stream banks and channels downstream from the development shall be protected from increased degradation by accelerated erosion caused by increased velocity of runoff from the construction activity. Supporting calculations may be required at the discretion of the Town’s Engineer.

See paragraphs 2.6.5 Channel Erosion Control and 2.7.4 Culvert Erosion Control, below, for downstream channel design requirements.

- E. Upstream Protection:**

1. Maximum allowable high water levels should be established along the storm drainage system prior to **initiating hydraulic** evaluations.
2. The **headwater elevation** of existing streams or pipe culverts upstream of the proposed development shall not be increased above the pre-development elevations from either the design storms shown in Table 2.6 or from a 100-year 24-hour storm event, whichever is greater.
3. Small drainage basins upstream of the proposed development shall be given consideration for the potential of flooding due to short duration high intensity storm events.
4. When applicable, evaluation of an upstream drainage basin shall be given consideration for the potential of grate clogging (i.e. yard and roadway grated inlets). **Assume a clogging factor of 50% for single grates in a sump condition.**
5. Any evaluation of the upstream drainage basin shall consider the potential impact of flooding existing upstream basements or near grade finished floors (slab-on-grade or crawl space) and make allowances to prevent the new development from increasing the pre-existing high water elevation.

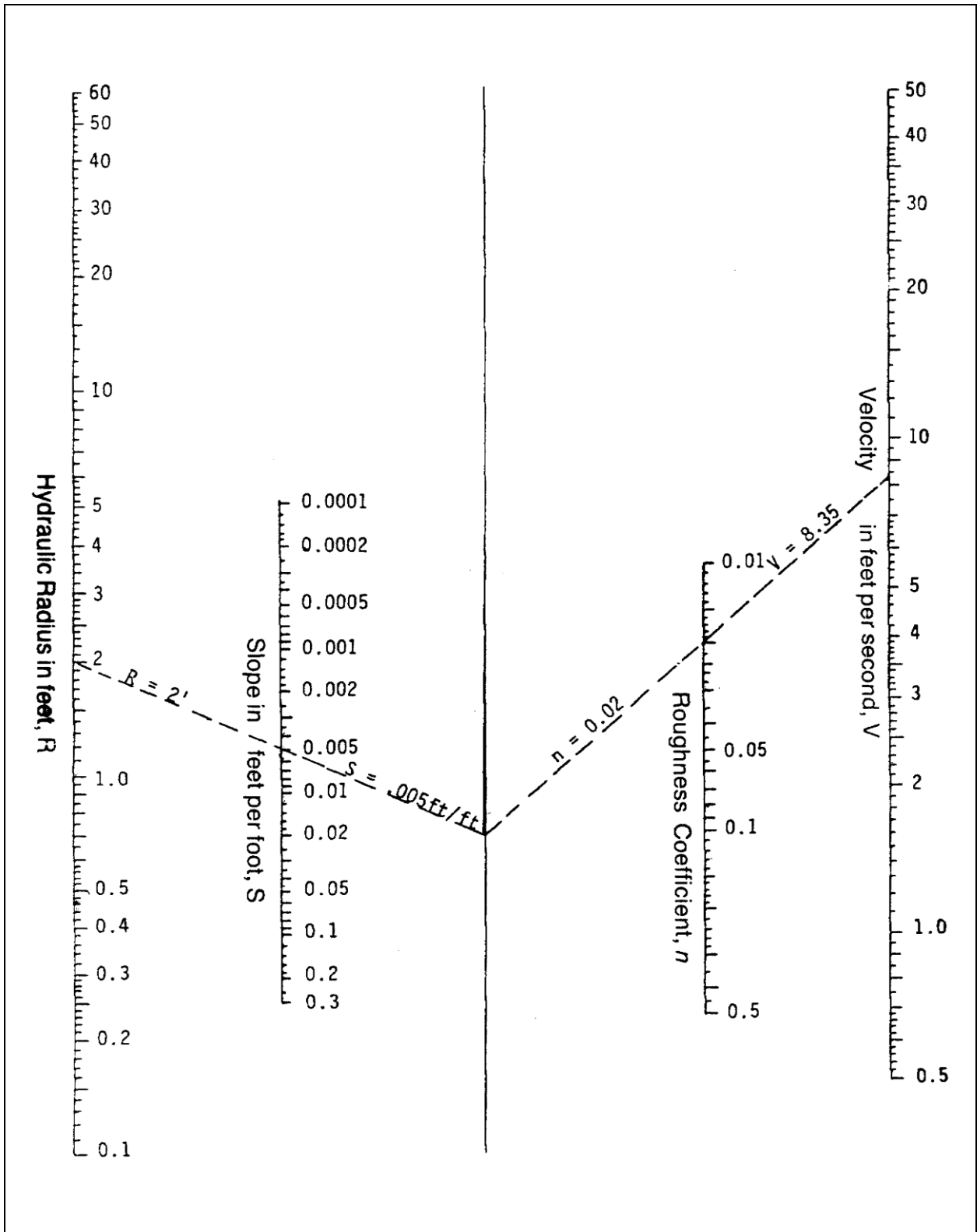
#### 2.6.5 CHANNEL EROSION CONTROL

- A. All erosion and sediment control measures shall be designed in accordance with the North Carolina Sedimentation Pollution Control Act of 1973, and the North Carolina Erosion and Sediment Control Handbook, latest edition.  
<http://portal.ncdenr.org/web/lr/publications>
- B. All Erosion and Sediment Control Plans measures shall be designed in accordance with the North Carolina Sediment Control Law and the Town of Wake Forest's Unified Development Ordinance, whichever is more stringent. The designer is to also reference this Manual of Specifications, Standards, and Design with regard to certain erosion control details required to be made part of the erosion and sedimentation control plan.
- C. The Town of Wake Forest has local review authority for erosion and sedimentation control plans. Erosion and Sedimentation Control plans, permit applications and fees shall be submitted to the Town of Wake Forest Engineering Department for review and approval.

#### 2.6.6 DESIGN AIDS

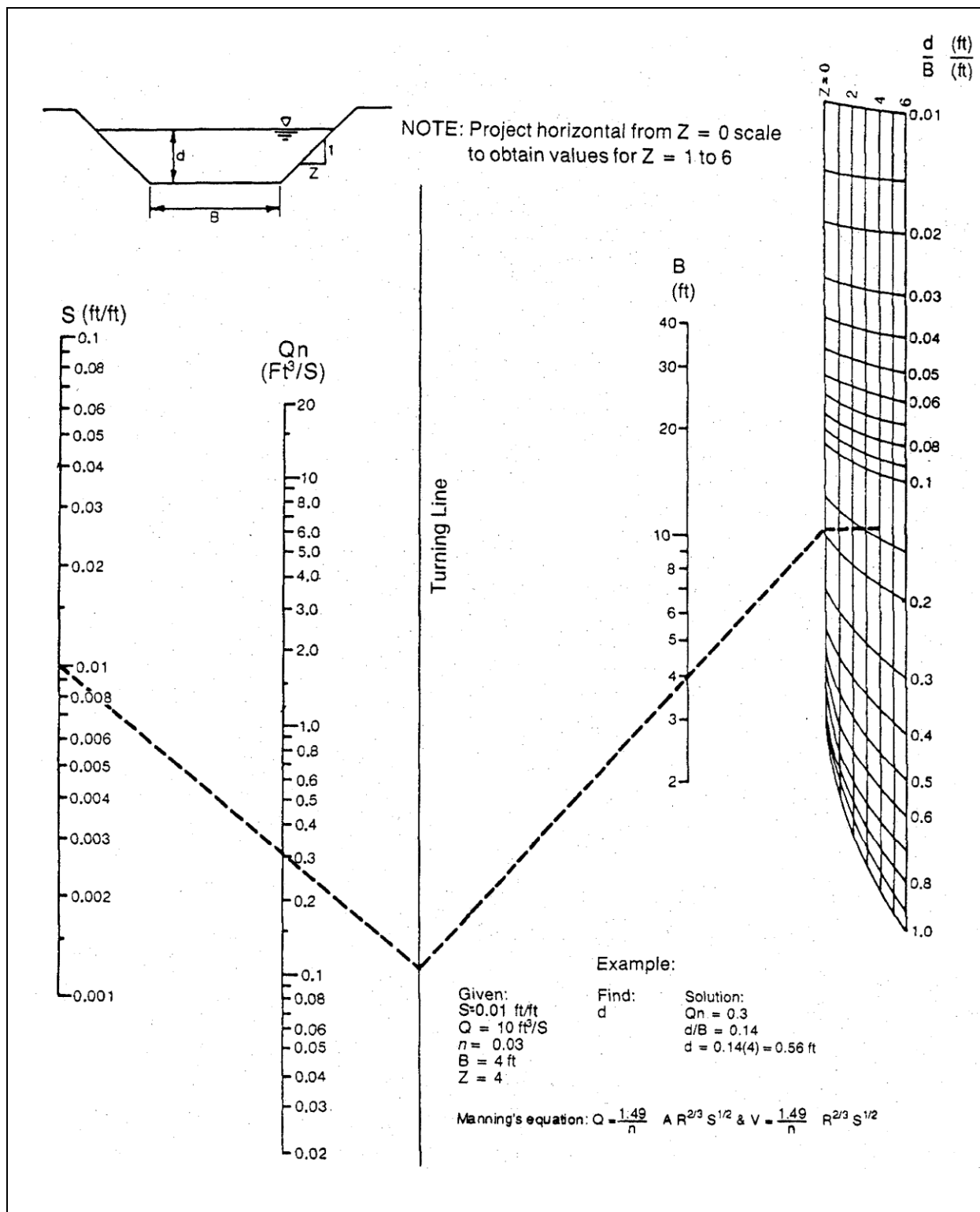
The following will aid in open channel design:

Figure 2.5 Nomograph for Solution of Manning Equation



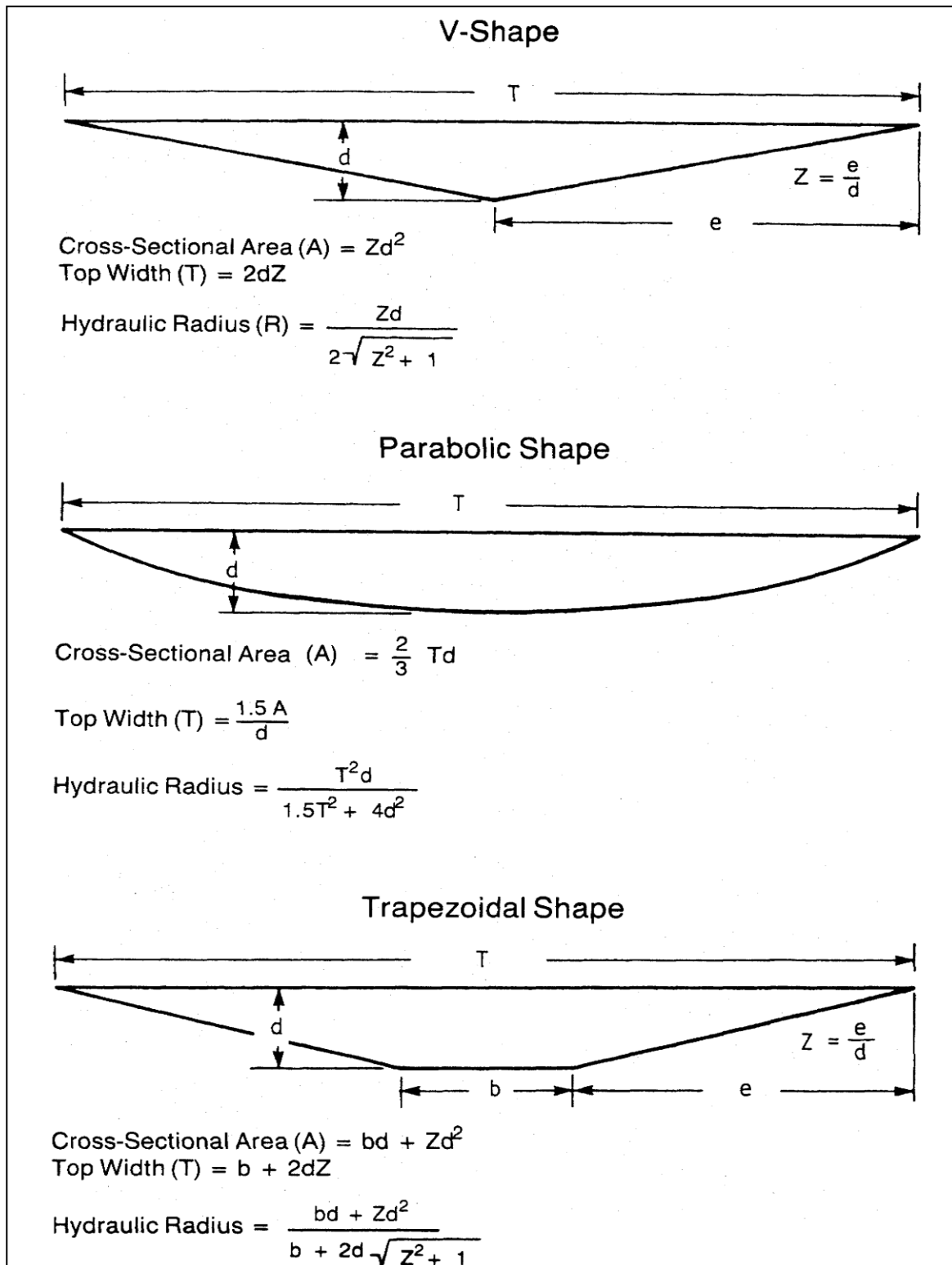
Source: [FHWA – HEC-15, 1988]

Figure 2.6 Solution of Manning's Equation for Trapezoidal Channels of Various Slope



Source: [FHWA – HEC-15, 1988]

Figure 2.7 Channel Geometries for V-Shape, Parabolic and Trapezoidal Channels



Source: ["E&amp;S Control Planning and Design Manual," DEHNR, May 1994 Revised]

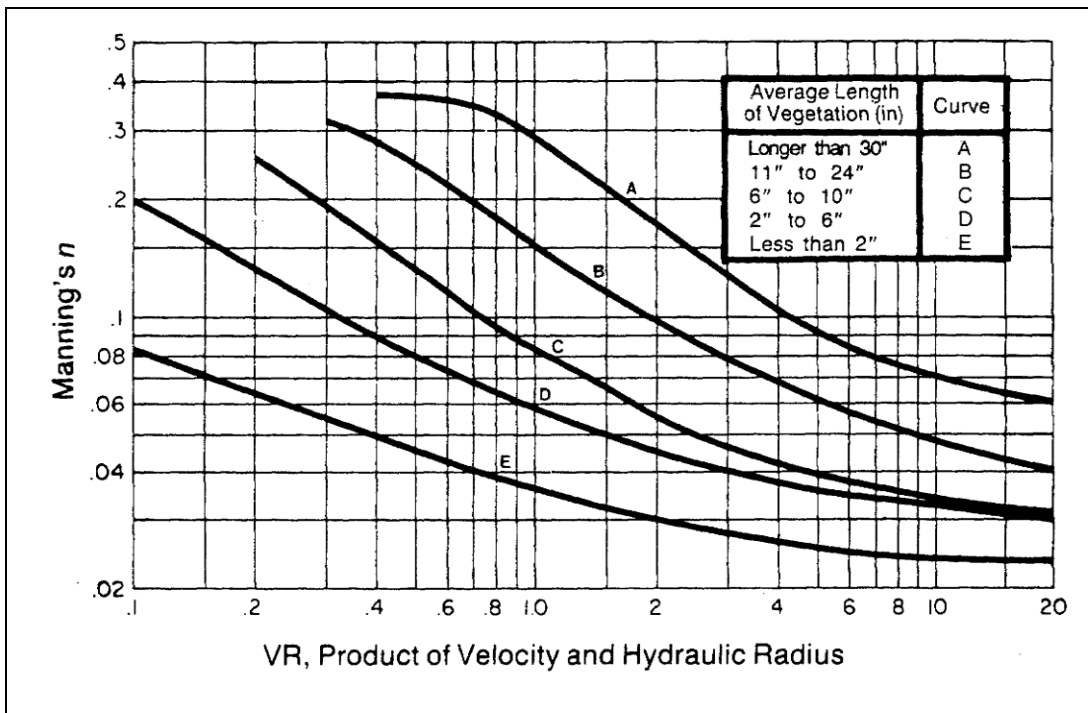
**Table 2.20 Maximum Allowable Design Velocities for Vegetated Channels**

Typical Channel Slope Application	Soil Characteristics <sup>2</sup>	Grass Lining	Permissible Velocity <sup>3</sup> for Established Grass Lining (ft/sec)
0-5%	Easily Erodible Non-Plastic (Sands & Silts)	Bermudagrass	5.0
		Tall Fescue	4.5
		Bahiagrass	4.5
		Kentucky bluegrass	4.5
		Grass-legume mixture	3.5
	Erosion Resistant Plastic (Clay Mixes)	Bermudagrass	6.0
		Tall Fescue	5.5
		Bahiagrass	5.5
		Kentucky bluegrass	5.5
		Grass-legume mixture	4.5
5-10%	Easily Erodible Non-Plastic (Sands & Silts)	Bermudagrass	4.5
		Tall Fescue	4.0
		Bahiagrass	4.0
		Kentucky bluegrass	4.0
		Grass-legume mixture	3.0
	Erosion Resistant Plastic (Clay Mixes)	Bermudagrass	5.5
		Tall Fescue	5.0
		Bahiagrass	5.0
		Kentucky bluegrass	5.0
		Grass-legume mixture	3.5
>10%	Easily Erodible Non-Plastic (Sands & Silts)	Bermudagrass	3.5
		Tall Fescue	2.5
		Bahiagrass	2.5
		Kentucky bluegrass	2.5
	Erosion Resistant Plastic (Clay Mixes)	Bermudagrass	4.5
		Tall Fescue	3.5
		Bahiagrass	3.5
		Kentucky bluegrass	3.5

Source: USDA-SCS Modified

NOTE: 1. Permissible Velocity based on 10-yr storm peak runoff.  
 2. Soil erodibility based on resistance to soil movement from concentrated flowing water.  
 3. Before grass is established, permissible velocity is determined by the type of temporary liner used.

Figure 2.8 Manning's "n" Related to Velocity, Hydraulic Radius and Vegetal Retardance



Source: [E&amp;S Control Planning and Design Manual," NCDENR, May 1994 Revised]



**Table 2.21 Retardance Classification for Vegetal Covers**

Retardance	Cover	Condition
A	Reed canarygrass	Excellent stand, tall (average 36")
	Weeping lovegrass	Excellent stand, tall (average 30")
B	Tall fescue	Good stand, uncut (average 18")
	Bermudagrass	Good stand, tall (average 12")
	Grass-legume mixture (tall fescue, red fescue, sericea lespedeza)	Good stand, uncut
	Grass mixture (timothy, smooth bromegrass, or orchardgrass)	Good stand, uncut (average 20")
	Sericea lespedeza	Good stand, not woody, tall (average 19")
	Reed canarygrass	Good stand, cut (average, 12-15")
	Alfalfa	Good stand, uncut (average 11")
C	Tall fescue	Good stand (8-12")
	Bermudagrass	Good stand, cut (average 6")
	Bahiagrass	Good stand, uncut (6-8")
	Grass-legume mixture- Summer (orchardgrass, redtop, and annual lespedeza)	Good stand, uncut (6-8")
	Centipedegrass	Very dense cover (average 6")
	Kentucky bluegrass	Good stand, headed (6-12")
	Redtop	Good stand, uncut (15-20")
D	Tall fescue	Good stand, cut (3-4")
	Bermudagrass	Good stand, cut (2.5")
	Bahiagrass	Good stand, cut (3-4")
	Grass-legume mixture- Fall-spring (orchardgrass, redtop, and annual lespedeza)	Good stand, uncut (4-5")
	Red fescue	Good stand, uncut (12-18")
	Centipedegrass	Good stand, cut (3-4")
	Kentucky bluegrass	Good stand, cut (3-4")
E	Bermudagrass	Good stand, cut (1.5")
	Bermudagrass	Burned stubble

Modified from: USDA-SCS, 1969. *Engineering Field Manual*.

**2.7 CULVERT DESIGN**

The purpose of this section is to establish standard procedures and criteria for Culvert Design for the Town of Wake Forest.

**2.7.1 INTRODUCTION**

- A. Drainage culverts shall be designed for the appropriate design and check storm per Table 2.6.
- B. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off-site areas, assuming ultimate development in accordance with the current zoning regulations and the Land Use Plan.

**2.7.2 CURB INLET DESIGN**

- A. Curb storm drainage inlets shall be provided at intervals along roadways. Where these inlets connect to storm sewers, a catch basin shall be installed with the inlet.
- B. The Town of Wake Forest uses the design procedures of Hydraulic Engineering Circular No. 22 (HEC 22), Urban Drainage Design Manual (HEC 12 "Drainage of Highway Pavements" was updated by the report of HEC 22). The procedures within HEC 22 analyze flow in gutters and the interception capacity of grate, curb-opening and slotted drain inlets as well as combination inlets.
- C. For curb and gutter inlets, a minimum intensity of 2 year storm at 5 minute time of concentration shall be used in all computations.
- D. Inlet spacing and sizing shall be adequate to limit the spread of water to ½ the travel lane into the roadway. The travel lane is the outside lane and does not include the gutter section.

Allowances shall be given for the potential of clogging at sumps. Due to clogging characteristics, the use of slotted drains alone are not recommended in sag locations.

**Table 2.22 Recommended Clogging Factors in Sump Condition<sup>1</sup>**

<b>1</b>	0.50	0.12
<b>2</b>	0.35	0.08
<b>3</b>	0.25	0.05
<b>4</b>	0.15	0.03

<sup>1</sup> Table 10.1, Urban Hydrology and Hydraulic Design, James C. Y. Guo, Water Resources Publication, LLC, (Observed Conditions).

- E. The curb inlet design procedure is based on the standard Town of Wake Forest curb inlet with a 4-foot opening. Inlets capture most of the water entering the pipe system. The following procedure is used to locate inlets, however, other factors shall be considered such as location of the low points, intersections and layout of the pipe system.
  - 1. Determine the maximum gutter flow from the nomograph "Flow in triangular gutter sections" (Figure 2.9) The known values of:
    - a.  $S$  = Street longitudinal slope,
    - b.  $S_x$  = Street cross slope,
    - c.  $T$  = 8 feet (the maximum allowable spread), and

- d.  $n$  = Manning's roughness coefficient are used to solve for the gutter capacity,  $Q$ .
2. Determine the location of the inlet using the rational formula rearranged such that:

$$A = \frac{Q}{Ci} \quad \text{(Equation 2.7)}$$

Where,

- $Q \rightarrow$  The peak rate of runoff in cubic feet per second (cfs). Actually,  $Q$  is in units of inches per hour per acre.
- $C \rightarrow$  The dimensionless coefficient of runoff representing the ratio of peak discharge per acre to rainfall intensity ( $i$ ).
- $i \rightarrow$  The average intensity of rainfall in inches per hour for a period of time equal to the time of concentration for the drainage area at the point of interest.
- $A \rightarrow$  The area in acres contributing runoff to the point of interest during the critical storm duration.

Locate the first inlet by trial and error using the existing site contours and the proposed designed plan such that the area of the sub-drainage area does not exceed the capacity determined using Equation 2.7. Remember to check the "C" value for the actual area determined.

3. The next inlets are located utilizing Figure 2.9 and 2.10. Determine the required curb opening length,  $L_t$ , and enter in Figure 2.10, with the ratio  $L/L_t$  where  $L$  is the actual curb opening in feet for Town of Wake Forest standard curb inlets. This will yield the percentage of flow intercepted by each basin. The remainder of this flow shall be considered in determining the location of the next downstream inlet. This procedure is repeated as necessary. The designer is encouraged to use the Catch Basin Design and Data Sheet, Figure 2.10.

### 2.7.3 PIPE CULVERT DESIGN - GENERAL

- A. Pipe culverts shall be aligned parallel to the longitudinal axis of the channel, as much as possible, to ensure maximum hydraulic efficiency and to minimize erosion. In areas where a change in alignment is necessary, the change shall be accomplished upstream of the culvert in the open channel. Appropriate erosion protection shall be provided.
- B. Pipe culverts crossing beneath the roadway shall be designed to span from ditch line to ditch line.
- C. All pipe culverts are required to have Flared End Sections or Headwall/Endwalls.
- D. The minimum pipe culvert diameter shall be 15 inches to minimize clogging and maintenance for all pipe culverts within Town of Wake Forest rights-of-ways and easements.
- E. All pipe culverts to be minimum Class III reinforced concrete with minimum pipe cover equal to 2 feet, measured from the proposed finished grade to the top of the pipe. Refer to Table 2 of Standard Detail 2.53 for the applicable laying conditions.
- F. Double Walled Corrugated HDPE is allowed outside of right-of-way only.

**2.7.4 CULVERT EROSION CONTROL**

- A.** Inlet and/or outlet protection is necessary to ensure those channels upstream and downstream of pipe culverts maintain stability and to avoid excessive transport and deposition of eroded material. Stream banks and channels downstream from any land disturbing activity shall be protected from increased degradation by accelerated erosion caused by increased velocity of runoff from the land disturbing activity.
- B.** All erosion and sediment control measures shall be designed in accordance with the North Carolina Sedimentation Pollution Control Act of 1973. The Designer is to reference the latest edition of the Erosion and Sediment Control Planning and Design Manual. This manual contains valuable information and tools for developing plans to minimize soil erosion and prevent sedimentation pollution associated with land-disturbing activities.
- C.** Persons shall conduct land disturbing activity so that the post construction velocity of runoff of the ten-year or twenty-five year storm (depending on watershed or HQW zone) in the receiving watercourse to the discharge point does not exceed the greater of:
  - a. The velocity established by the Maximum Permissible Velocities Table or
  - b. The velocity of the ten-year storm runoff in the receiving watercourse prior to the development.
  - c. If condition 1 or 2 cannot be met, then the receiving watercourse to and including the discharge point shall be designed and constructed to withstand the expected velocity anywhere the velocity exceeds the pre development velocity by 10%.

Maximum Permissible Velocities Table

<u>Material</u>	<u>Velocity (fps)</u>
Fine sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary firm loam	3.5
Fine gravel	5.0
Stiff clay (very colloidal)	5.0
Graded, loam to cobbles (noncolloidal)	5.0
Graded, silt to cobbles (colloidal)	5.5
Alluvial silts (noncolloidal)	3.5
Alluvial silts (colloidal)	5.0
Course gravel (noncolloidal)	6.0
Cobbles and shingles	5.5
Shales and hard pans	6.0

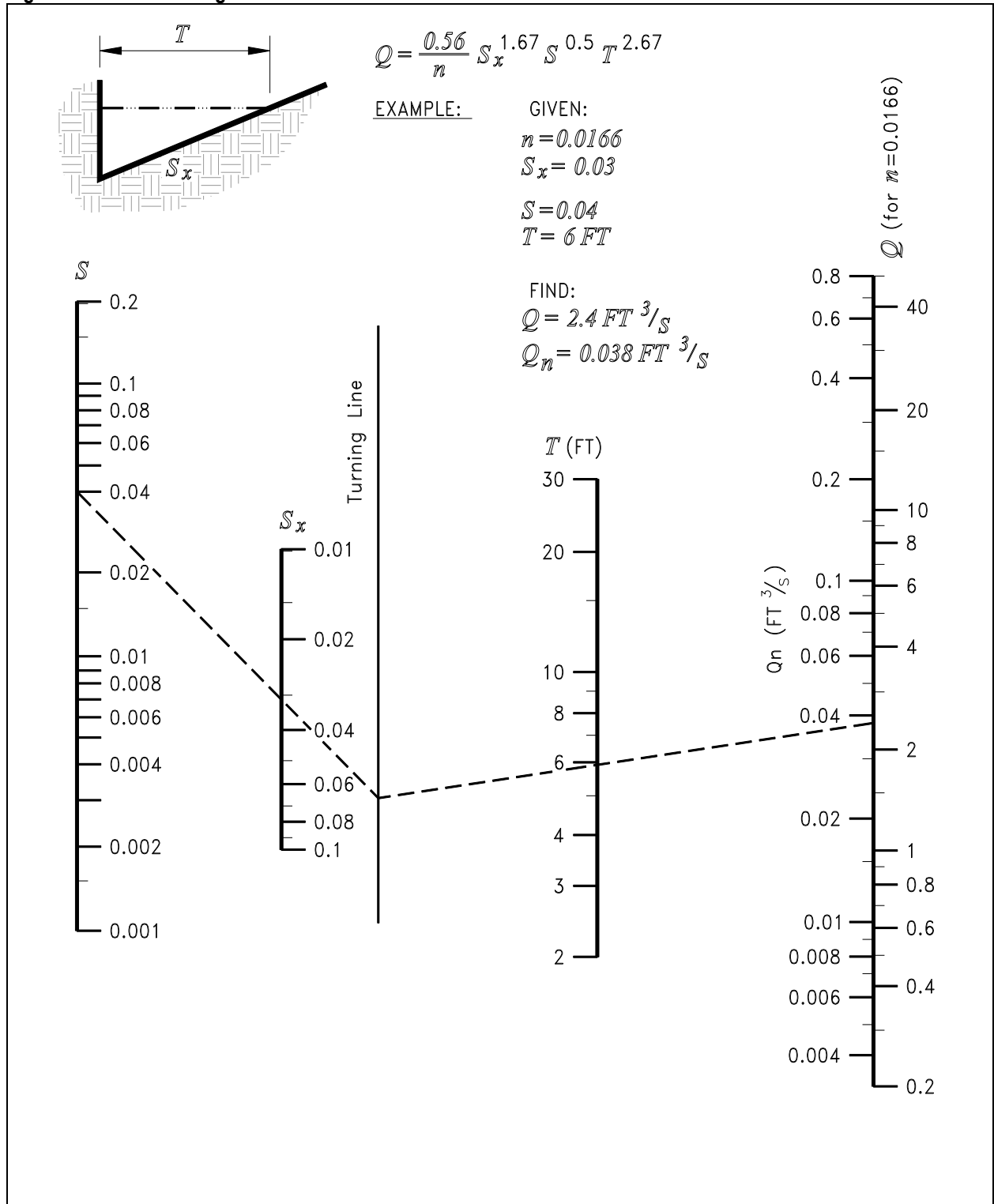
*Source: [adopted from recommendations by Special Committee on Irrigation Research, American Society of Civil Engineering 1926, for channels with straight alignment. For sinuous channels, multiple allowable velocity by 0.95 for slightly sinuous, 0.90 for moderately sinuous, and by 0.80 for highly sinuous channels]*

- D.** Acceptable Management Measures - Measures applied along or in combination to satisfy the intent of the Ordinance area acceptable if there are no objectionable secondary consequences. The Town recognizes that the management of storm water runoff to minimize or control downstream channel and bank erosion is a developing technology. Innovative techniques and ideas will be considered and may be used when shown to the potential to produce successful results. Some alternatives, while not exhaustive are to:
- a. Avoid increases in surface runoff volume and velocity by including measures to promote infiltration to compensate for increased runoff from areas rendered impervious.
  - b. Avoid increased in storm water discharge velocities by using vegetated or roughened swales and waterways in place of closed drains and high velocity paved sections.
  - c. Provide energy dissipaters at outlets of storm drainage facilities to reduce flow velocity at the point of discharge from the development; these may range from simple riprap sections to complex structures.
  - d. Protect watercourses subject to accelerated erosion by improving sections and/or providing erosion resistant lining.
  - e. Upgrade or replace the receiving device structure, or watercourse such that it will receive and conduct the flow to a point where it is no longer subject to degradation from the increased rate of flow or increased velocity.

#### **2.7.5 DESIGN AIDS**

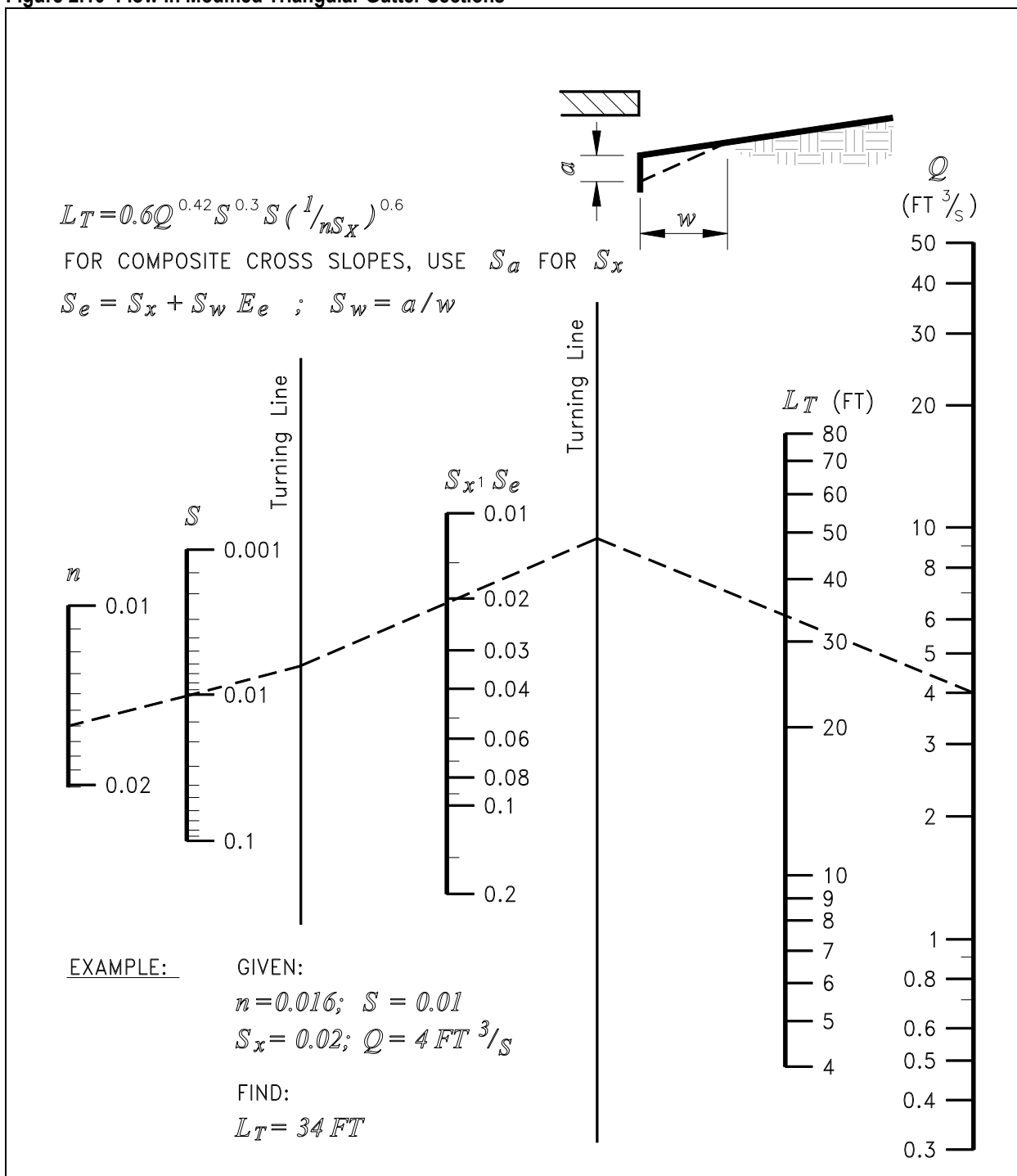
The following charts, tables, figures, etc., will aid in pipe culvert design:

Figure 2.9 Flow in Triangular Gutter Sections



Source: [FHWA-TS-84-202]

Figure 2.10 Flow in Modified Triangular Gutter Sections



Source: [FHWA-TS-84-202]

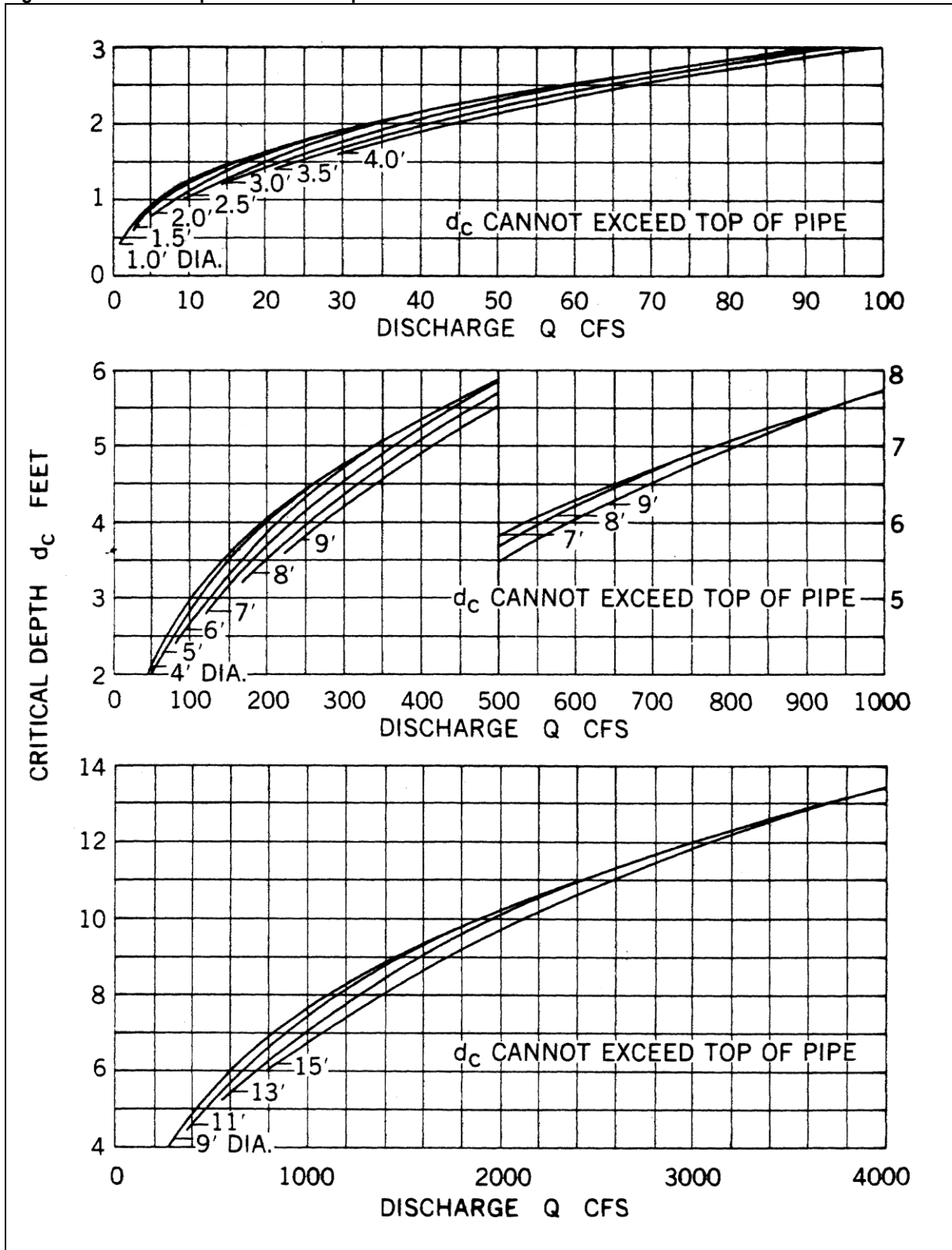
[illegible]

Source: City of Wilmington Technical Standards and Design, [July 1996]



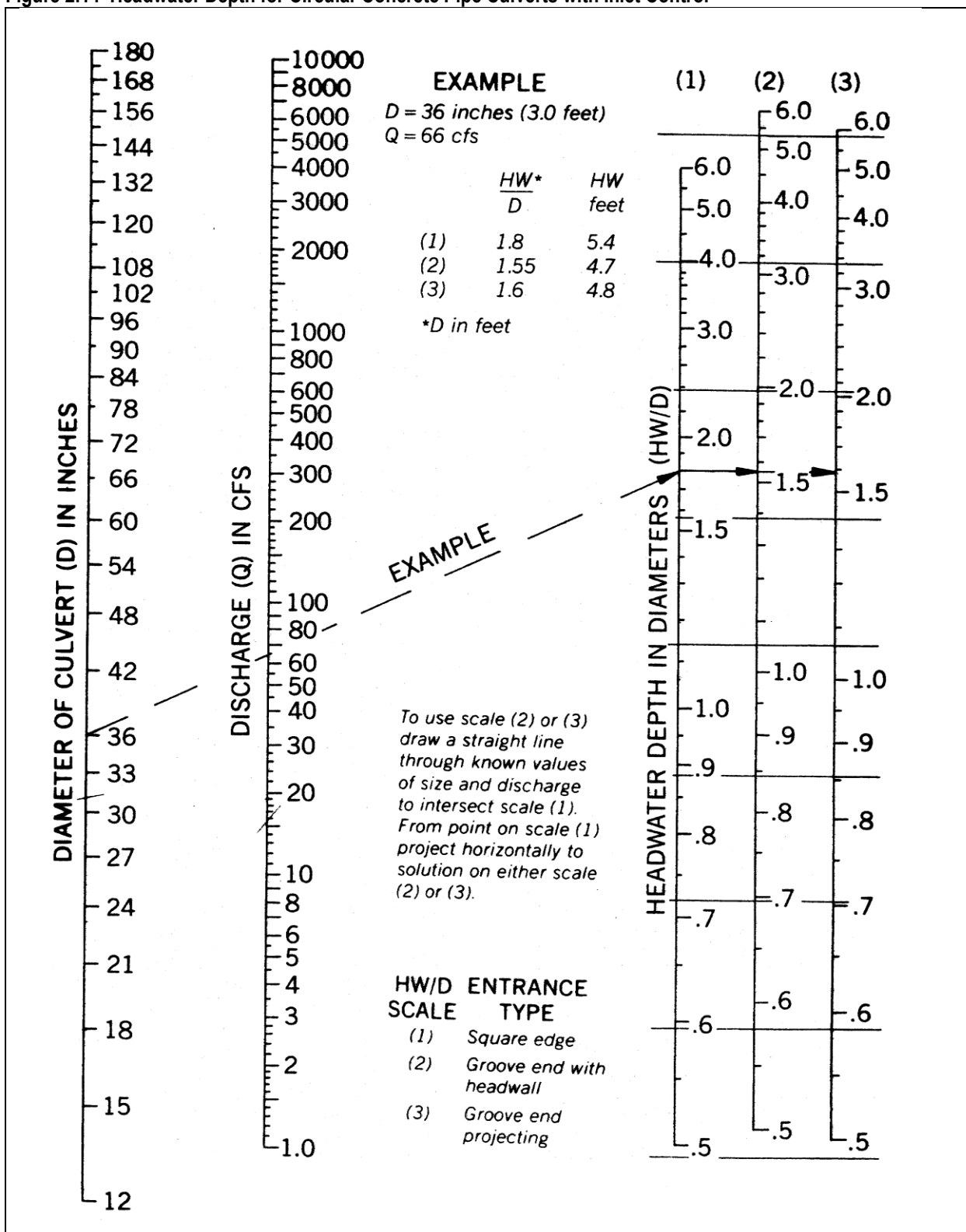


Figure 2.13 Critical Depth for Circular Pipe



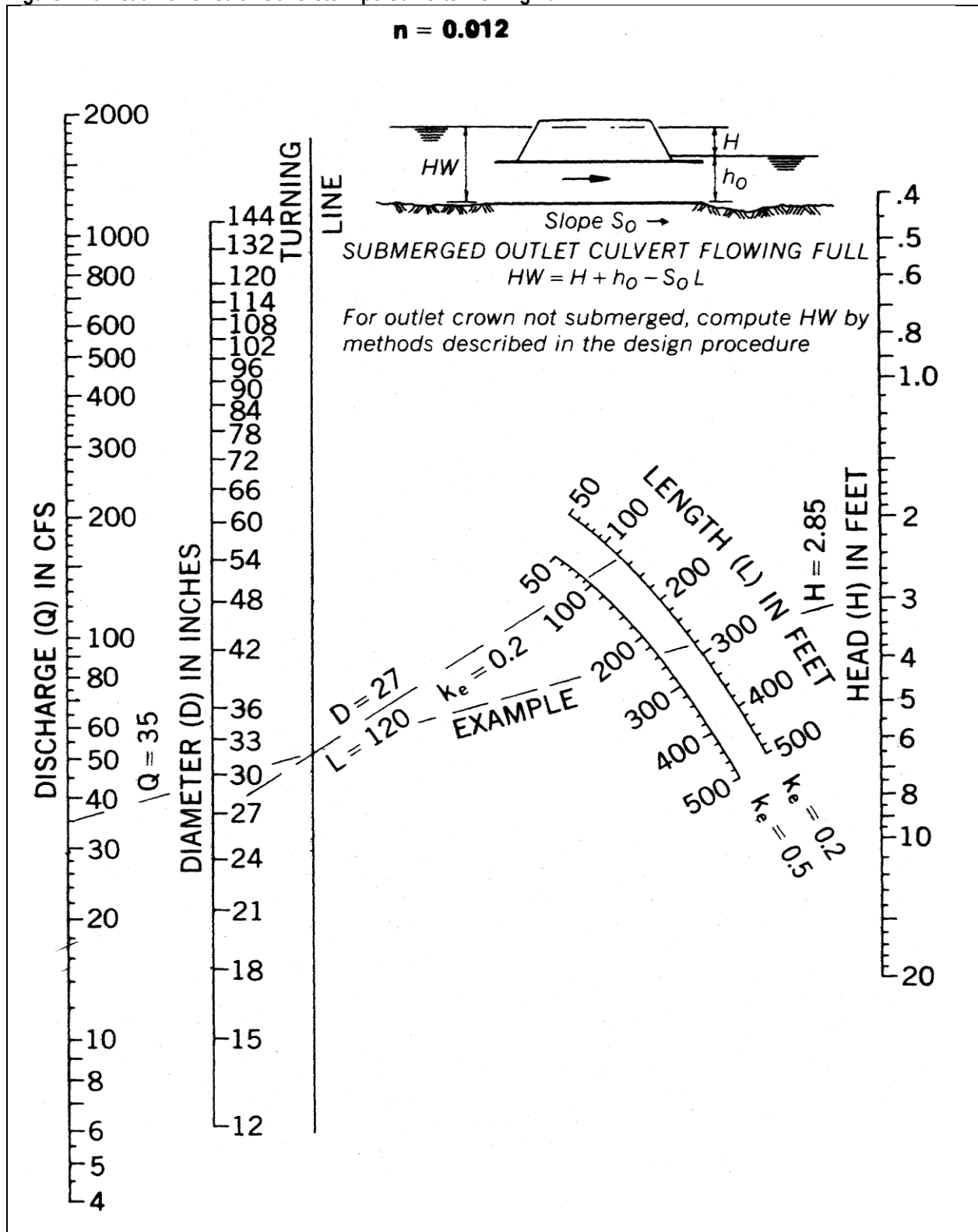
Source: [Bureau of Public Roads, 1963]

Figure 2.14 Headwater Depth for Circular Concrete Pipe Culverts with Inlet Control



Source: [Bureau of Public Roads, 1963]

Figure 2.15 Head for Circular Concrete Pipe Culverts Flowing Full



Source: [Bureau of Public Roads, 1963]

## 2.8 BEST MANAGEMENT PRACTICES (BMPs)

### 2.8.1 INTRODUCTION

- A.** Management of nonpoint source discharge is a stated goal of the 1987 Water Quality Act. An important source of these pollutants is stormwater runoff from urban and developing areas. This runoff has the potential to degrade water quality in all types of waters, including, among others, those classified as water supply watersheds, shellfish areas, and nutrient sensitive waters. The management of stormwater runoff through nonstructural controls (e.g., low-density development) is the preferred method of reducing pollution from urban areas. In cases where low density is not feasible, engineered stormwater controls are a viable solution to reducing pollution. However, proper design, and subsequent management, of these engineered solutions is essential for adequate pollutant removal.
- B. Function of BMPs as Intended:** The Owner of each structural BMP installed shall maintain and operate it so as to preserve and continue its function in controlling stormwater quality and quantity as originally designed. Refer to Section 2.9, Inspection, Acceptance and Maintenance.

### 2.8.2 NCDENR BMP MANUAL

Designer is to refer to the NCDENR Stormwater Best Management Practices Manual, latest revision (<http://portal.ncdenr.org/web/lr/bmp-manual>), and this manual. Note that in any discrepancy between the NCDENR BMP Manual and the Town of Wake Forest Manual of Specifications, Standards and Design or the Unified Development Ordinance, the more stringent of the requirements apply.

### 2.8.3 DESIGN CONSIDERATIONS

#### A. Location

1. It is recommended that stormwater BMP facilities be located on the site from which the runoff to be controlled is generated. However, off-site facilities are acceptable in accordance with NCDENR regulations provided that the land area involved with the facility is delineated and officially recorded at the Wake County Register of Deeds office as a permanent “Stormwater BMP Easement.” The property Owner on which the facility is located will also be required to submit to the Town a letter of commitment to the maintenance of the facility.
2. In no case shall a habitable structure be located within the BMP area of any stormwater storage facility. No utilities (sewer lines, power lines, water lines, etc.) shall be located within or immediately around any BMP facility.

**B. Safety Considerations:** Adequate safety measures such as warning signs, embankment slopes, fences, grates, and other features should be incorporated into the design of the facility wherever appropriate.

**C. Proprietary BMP Systems** may be allowed by the Town’s Engineer in accordance with the specifications outlined by the NCDENR BMP Manual, Chapter 20, “Proprietary Systems.”  
[http://portal.ncdenr.org/c/document\\_library/get\\_file?uuid=2502ccc0-339a-447d-90e2-79375c02f97b&groupId=38364](http://portal.ncdenr.org/c/document_library/get_file?uuid=2502ccc0-339a-447d-90e2-79375c02f97b&groupId=38364).

### 2.8.4 STORMWATER DETAILS

Standard Details 2.50 through 2.76 are herein made part of this section by reference and should be utilized in conjunction with NCDENR’s BMP Manual. The more restrictive shall apply.

**2.9 INSPECTIONS, ACCEPTANCE & MAINTENANCE****2.9.1 LIMITS OF PUBLIC OWNERSHIP AND MAINTENANCE RESPONSIBILITY**

- A. All drainage easements carrying water from the right of way or public property shall be public and maintained by the Town of Wake Forest.
  - 4. The Town of Wake Forest assumes no liability or responsibility for adjudicating disputes between property owners regarding non-publicly generated storm water.
- B. Drainage systems maintained by NCDOT as part of its State highway system.
- C. Detention/Retention/Water Quality Pond & Other BMP's: The Town will not accept these areas/structures for maintenance; however, the Town reserves the right to enter to routinely inspect these areas and address any items that would cause BMP(s) to be noncompliant. This will be done in an emergency situation without notice. Under normal conditions, the Town will contact the Owner/developer to have said items addressed. If unable to do so within a reasonable time, the Town reserves the right to charge the Owner/developer for any expense incurred by the Town in doing so.

**2.9.2 LIMITATION OF CONSEQUENTIAL DAMAGE TO PRIVATE FACILITIES LOCATED ON PUBLIC EASEMENTS**

All public easements including storm sewer are to remain clear of obstructions. No buildings, fences, trees, shrubs or other obstructions shall be placed in any easement. Driveways, walkways, asphalt and parking lots may be permitted in easements; however, the Town reserves the right to remove such asphalt, concrete, base course and sod as necessary to access its facility in the case of emergency. Pavement or concrete will be replaced with a patch. Sod will be replaced with seeding like or similar grass. The Town will not be responsible for replacing a property owner's sod after repairing a drainage line.

**2.9.3 ITEMS NEEDED FOR ACCEPTANCE**

- A. The following is required to be submitted prior to acceptance for each stormwater management BMP facility, control and device:
  - 1. **Sealed As-Built drawings.** Refer to Section 2.9.3.B
  - 2. **As-Built Certification by the Designer.** Refer to Section 2.9.3.C
  - 3. **Operation and Maintenance Plan.** Refer to Section 2.9.3.D
  - 4. **Legal Operation and Maintenance Agreement.** Refer to Section 2.9.3.E
  - 5. **Performance Security for Installation and Maintenance.** Refer to Section 2.9.F
- B. **Sealed as-built drawings** shall be submitted after final inspection and prior to acceptance, as follows:
  - 1. Upon completion of a project, and **before a Certificate of Occupancy** shall be granted, the applicant shall certify that the completed project is in accordance with the approved stormwater management plans and designs, and shall submit actual field surveyed "as built" plans for all stormwater management BMP facilities or practices after final construction is completed.

2. The as-built plans shall be prepared by a professional land surveyor (PLS) or professional engineer (PE) registered to practice in North Carolina. Applicant to provide (2) sealed paper copies and (1) digital copy on CD (compact disk), consistent with the programs used by the Town of Wake Forest GIS Department. Field survey/ as-built to be tied to NC grid system.
3. The plans shall show the final design specifications for all stormwater management facilities and practices and the field surveyed contours, pipe size, pipe location, invert elevations and planted vegetation (if applicable) of all measures, controls, and devices, as installed. Detailed drawings for each stormwater control device shall be submitted to the Town's Engineer.
4. The as-built plans shall show all recorded drainage and access easements for each BMP, referencing book map and page number.

#### C. As-Built Certification

1. The Designer of the stormwater management measures and plans shall certify, under seal, that the as-built stormwater measures, controls, and devices are in compliance with the approved stormwater management plans and designs and with the requirements of this Manual.
2. Designer to provide a written statement bearing his seal stating that he has performed a thorough inspection of all required stormwater control facilities and that they are installed and performing in compliance with the approved stormwater control plan. Designers are to use the Town of Wake Forest **As-Built Certification Form**, *Form SW200*, found in Section 2.12 of this manual and online at: <http://www.wakeforestnc.gov>.
3. The following items must be inspected during and/or after installation of storm drainage lines and appurtenances, as applicable:
  - a. All boxes and manholes for presence of weep holes, formed inverts, bolted down castings, pipe flushed against inside wall of box, steps and location of steps, proper corbeling of brick/block in accordance with the details and specs, wall thickness and depth of manhole.
  - b. Pipe for cracks, pipe markings for compliance with specifications (painted and etched).
  - c. Removal of debris and sediment in both pipe and box.
  - d. Rip rap outlet protection and filter fabric, stilling basin compliance with plan
  - e. Manhole casting cover reading "storm drainage."
  - f. Armor protection of ditches (concrete and/or temporary liners), scour and erosion.

#### D. Operation and Maintenance Plan

1. For each type of BMP, provide description of BMP features requiring inspection, inspection frequency, types and frequencies of or basis for routine and periodic maintenance activities, actions in the event that repair is needed. Maintenance actions and frequencies shall at minimum include those identified by practice in the NCDENR BMP Manual. The Town of Wake Forest requires submittal of the Operation and Maintenance Agreement Forms provided in the NCDENR BMP Manual, online at: <http://portal.ncdenr.org/web/lr/bmp-manual>.

2. Name, address and contact telephone numbers of all current officers of the company or Owner's Association. Any changes in this information during the year shall be provided to the Town's Engineer within 30 days of the change.
3. For HOAs and other associations, description of method used to collect dues or other payments necessary for maintenance of BMPs.
4. Depending on the BMPs constructed the plan might include schedules or other provisions for:
  - a. Any mowing of permanent vegetation.
  - b. Any removal of bushes and trees from the dam of a wet detention pond.
  - c. Reseeding of any eroding areas of the wet detention ponds, open channel practices, riparian buffers and vegetated filter strips.
  - d. Replacing of impaired vegetation in a constructed wetlands or riparian buffer.
  - e. Removal of debris from the "trash rack" on any wet detention pond or sand filter.
  - f. Repair of any damage to structural aspects of wet detention ponds, constructed wetlands, level spreaders, and sand filters.
5. **Annual BMP Inspections Certification** is required on *Form SW210*, as described in Section 2.9.3.C.

#### E. Operation and Maintenance Legal Agreement

1. Prior to the conveyance or transfer of any lot or building site to be served by a required engineered stormwater, and prior to issuance of any permit for development requiring a engineered stormwater control pursuant to this ordinance, the applicant or Owner of the site must execute a **legal Operation and Maintenance agreement** that shall be binding on all subsequent owners of the site, portions of the site, and lots or parcels served by the engineered stormwater control. Until the transference of 80% of all property, sites, or lots served by the engineered stormwater control, the original owner or applicant shall have primary responsibility for carrying out the provisions of the maintenance agreement.
2. The legal Operation and Maintenance agreement shall require the owner or owners to maintain, repair and, if necessary, reconstruct the engineered stormwater control, and shall state the terms, conditions, and schedule of maintenance for the engineered stormwater control. In addition, it shall grant to the Town a right of entry in the event that the Town has reason to believe it has become necessary to inspect, monitor, maintain, repair, or reconstruct the structural BMP; however, in no case shall the right of entry, of itself, confer an obligation on Town to assume responsibility for the structural BMP.
3. The **Operation and Maintenance Agreement** must be approved by the Town prior to plan approval, and it shall be referenced on the final plat and shall be recorded with the county Register of Deeds upon final plat approval. A copy of the recorded maintenance agreement shall be given to the Town within 14 days following its recordation. An example Operation and Maintenance Agreement may be found in Section 2.12 of this manual and online at: <http://www.wakeforestnc.gov>.
4. The Operation and Maintenance agreement shall contain the following elements:



- a. Annual Maintenance Plan
- b. **Annual BMP Inspection Report**, per Section 2.9.3.C.
- c. Contact Information
- d. Authority

**F. Performance Security for Installation and Maintenance:**

1. The Town may, at its discretion, require the submittal of a performance security or bond with surety, cash escrow, or other acceptable legal arrangement prior to issuance of a permit in order to ensure that the engineered stormwater controls are:
  - a. Installed by the permit holder as required by the approved stormwater management plan; and/or
  - b. Maintained by the Owner as required by the operation and maintenance agreement.
2. In lieu of a performance security, bond, or cash escrow for Homeowner's Associations, the Town may, at its discretion, accept the Association's budget and other financial documentation that ensures that the Association will have sufficient finances for the installation and maintenance of the approved stormwater management plan. Such a decision will be made by the Town's Engineer on a case by case basis.
3. The amount of an installation performance security shall be in the amount of 110% of the cost estimate for the BMP. The performance bond may be reduced to 25% at the time the Certificate of Occupancy is issued to satisfy the requirement for the one year warranty period.
4. Within sixty days of the final approval, the installation performance security shall be refunded to the applicant or terminated, except any amount attributable to the cost (plus 25%) of landscaping installation and ongoing maintenance associated with the BMPs covered by the security. Any such landscaping shall be inspected one (1) year after installation with replacement for compliance with the approved plans and specifications and, if in compliance, the portion of the financial security attributable to landscaping shall be released.
5. The performance security shall contain forfeiture provisions for failure, after proper notice, to complete work within the time specified, or to initiate or maintain any actions which may be required of the applicant or Owner in accordance with this ordinance, approvals issued pursuant to this ordinance, or an operation and maintenance agreement established pursuant to this ordinance
6. Upon default of the *Owner* to construct, maintain, repair and, if necessary, reconstruct any engineered stormwater control in accordance with the applicable permit or operation and maintenance agreement, the Town shall obtain and use all or any portion of the security to make necessary improvements based on an engineering estimate. Such expenditure of funds shall only be made after requesting the Owner to comply with the permit or maintenance agreement. In the event of a default triggering the use of installation performance security, the Town may not return any of the unused deposited cash funds or other security.

7. If Town takes action upon such failure by the applicant or Owner, the Town may collect from the applicant or Owner the difference between the amount of the reasonable cost of such action and the amount of the security held, in addition to any other penalties or damages due.
- G. A final inspection and approval by the Town's Engineer may be required before the release of any performance securities.
- H. **Signage:** Where appropriate in the determination of the Town of Wake Forest to assure compliance with the MSSD and Unified Development Ordinances, structural BMPs shall be posted with a conspicuous sign stating who is responsible for required maintenance and annual inspection. The sign shall be maintained by the Owner so as to remain visible and legible.

#### 2.9.4 SPECIAL REQUIREMENTS FOR HOME OWNERS AND OTHER ASSOCIATIONS

For all structural BMPs required pursuant to this manual and that are to be or are owned and maintained by a homeowners' association, property owners' association, or similar entity, the required operation and maintenance agreement shall include all of the provisions described in the Unified Development Ordinance, Section 12.5.6.F.

#### 2.9.5 MAINTENANCE

The long-term effectiveness of any engineered stormwater control relies, above all, on appropriate maintenance. This section provides provisions to ensure that such maintenance occurs, including identifying who will be responsible for maintenance over the long term as well as during development, and ensuring that funds for maintenance and repair are available when appropriate. The Town is required to ensure that BMPs implemented to achieve nutrient reduction and flow attenuation requirements are maintained and inspected on a yearly basis.

- A. **Function of BMP as Intended:** The Owner of each engineered stormwater control installed pursuant to this ordinance shall maintain and operate it so as to preserve and continue its function in controlling stormwater quality and quantity at the degree or amount of function for which the engineered stormwater control was designed.
- B. **Records:** Records of maintenance and/or repair activities shall be maintained by the Owner for at least 5 years and shall be provided to the Town upon request.
- C. **Annual Inspection:**

The person responsible for maintenance of any required engineered stormwater control shall submit to the Town's Engineer an annual inspection report from one of the following persons performing services only in their area of competence: a qualified registered North Carolina professional engineer, surveyor, landscape architect, soil scientist, aquatic biologist, or person certified by the North Carolina Cooperative Extension Service for stormwater treatment practice inspection and maintenance.

1. The inspection report shall contain all of the following:
  - a. The name and address of the land owner;
  - b. The recorded book and page number of the lot of each engineered stormwater control;
  - c. A statement that an inspection was made of all engineered stormwater controls;
  - d. The date the inspection was made;

- e. A statement that all inspected engineered stormwater controls are performing properly and are in compliance with the terms and conditions of the approved maintenance agreement required by this ordinance; and
  - f. The signature and seal of the engineer, surveyor, or landscape architect.
  - g. A narrative describing the general condition of the site.
  - h. A narrative for each BMP that describes in detail its current condition.
  - i. Photographs to document sufficiently the current condition of all structures and features.
2. Special attention should be made to the following items, which should be discussed in the narratives for each BMP:
- a. Has sediment built up in the inlet, outlet, or forebay?
  - b. Are there signs of erosion or any denuded areas?
  - c. Is there trash or debris that needs to be removed? (This is particularly important at outlet structures.)
  - d. Are algae, aquatic weeds, or invasive plants (particularly cattails) present?
  - e. Is there evidence of cracks, separation, or alignment problems with pipes?
  - f. Are rip-rap dissipator pads damaged, clogged with vegetation, or insufficient?
  - g. For dry detention ponds, is the basin holding water longer than 5 days after a storm event
  - h. Is there evidence of muskrat or beaver activity?
  - i. Are vegetated slopes steeper than 3:1?
  - j. Is there evidence of depressions in the soil surface over or around any pipes?
3. **Failed Inspection:** If the BMPs have major deficiencies (system failure) and must be repaired in order to function properly and operate as designed, the Annual BMP Inspection Report form and supporting documentation must be completed by the deadline, but the registered professional is not obligated to sign and seal the form.
- a. The Owner is responsible for correcting all deficiencies identified in the report, obtaining a re-inspection following repairs, and submitting a revised Annual BMP Inspection Report, **within 30 days** after the deadline.
4. **Conditional Approval:** If the BMPs have minor deficiencies (system operates, but repair is needed to ensure the system does not fail), the Annual BMP Inspection Report form and supporting documentation must be completed by the deadline, but the registered professional is not obligated to sign and seal the form.
- a. The Owner is responsible for correcting all deficiencies identified in the report, obtaining a re-inspection following repairs, and submitting a revised Annual BMP Inspection Report, **within 30 days** after the deadline.

5. **Annual BMP Inspection Report Form:** All inspection reports shall be on forms supplied by the Town. An original inspection report shall be provided to the Town's Engineer prior to January 1 of each year. The Town of Wake Forest **Annual BMP Inspection Report Form**, *Form SW210*, is found in Section 2.12, Appendix, and online at: <http://www.wakeforestnc.gov>.

### 2.9.6 WARRANTY

#### A. Warranty and Defects Guarantee:

1. Upon the acceptance of facilities, utilities or streets for permanent maintenance, a one-year warranty for all improvements shall become effective. This warranty must be satisfactory to the Town of Wake Forest. In addition, the subdivider shall provide surety in the amount of 15% of the total construction cost to guarantee the correction of all defects in such facilities, utilities or streets that occur within the warranty period described above.
2. For the purposes of this section, the term "defects" refers to any condition in publicly dedicated facilities, utilities or streets that requires the Town to make repairs to such improvements over and above the normal amount of maintenance that they would require. If such defects appear, the warranty may be enforced regardless of whether the facilities, utilities or streets were constructed in accordance with the requirements of this manual.

- B. During the one-year warranty period the developer shall repair any latent defects which occur. At the end of the one-year warranty period the developer shall request a final inspection. Upon successful completion of all warranty items the developer shall be released from maintenance responsibilities for the warranted construction.

#### C. Warranty repairs to the following common problems shall be as follows:

1. Water & Sewer Trench Failures: Street pavement trench failures shall be repaired in accordance with the City of Raleigh Public Utilities Handbook.
2. Storm Drainage & Other Utility Trench Failures: Street pavement trench failures shall be repaired in accordance with Standard Detail 2.06.
3. If more than 3 trench failures occur within a longitudinal distance of 800 feet on any segment of a street, the Town shall require a 1-inch overlay once repairs have been completed.
4. Cracks in sidewalk and/or curb and gutter shall be repaired by removing and re-pouring such sections as necessary;
5. All storm sewer systems, ditches and gutters shall be free of debris, dirt or silt;
6. All drainage and street appurtenances shall be in perfect condition and properly exposed.
7. All other defects shall be corrected in accordance with the recommendations of the Town's Engineer or his representative;

- D. **If a developer fails to complete warranty items, future projects of the developer shall not be reviewed by the Town. The Town may take additional legal action against the developer.**

### 2.9.7 INSPECTION PROGRAM

- A. Inspections and inspection programs by the Town of Wake Forest may be conducted or established on any reasonable basis, including but not limited to

routine inspections; random inspections; inspections based upon complaints or other notice of possible violations; and joint inspections with other agencies inspecting under environmental or safety laws. Inspections may include, but are not limited to, reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in BMPs; and evaluating the condition of BMPs.

- B. If the Owner or occupant of any property refuses to permit such inspection, the Administrator shall proceed to obtain an administrative search warrant pursuant to NCGS 15-27.2 or its successor.
- C. All inspections must be scheduled the day prior to when needed. Inspections will be performed in the order received. Every effort will be made to accommodate the time of request, however, this cannot be guaranteed.
- D. All inspections that fail are subject to a re-inspection fee according to the Town's Comprehensive List of Fees and Charges.
- E. Upon completion of construction the developer shall request a warranty inspection. Upon completion of all punch list items, the provision of a set of acceptable record drawings, and the submission of engineer's certifications, a one-year warranty period shall commence.

#### 2.9.8 FAILURE TO COMPLY

Any violation of the Maintenance agreement shall be considered a violation of the Unified Development Ordinance and shall be enforced in accordance with the Town of Wake Forest UDO. In addition, if the situation meets the definition of a nuisance as defined in NCGS 153A-140 other corrective actions may be taken.

### 2.10 PIPE POLICY – MATERIAL / INSTALLATION

All materials and installation procedures, testing and acceptance of all publicly dedicated drainage infrastructures shall meet the requirements of the Town of Wake Forest Manual on Specifications and Design.

#### 2.10.1 PURPOSE AND DEFINITION

The purpose of this policy is to establish a written standard on the type of pipe to be used in a ditch or tributary carrying storm water run-off from a dedicated public street or from property owned and maintained by the Town (herein "public water") which is either subject to review, maintenance or inspection by the Town or located within either the Town limits of Wake Forest or under its extraterritorial jurisdiction.

#### 2.10.2 PIPE MATERIAL

- A. Storm drainage pipe, covered by the definition in paragraph 2.10.1 of this section, shall be reinforced concrete pipe except for the following exemption:
  - 1. Pipe is 12" I.D. or smaller, made of plain concrete, and is to be used in residential drives or roadside ditches. The Town of Wake Forest Engineering staff will determine the size required.
  - 2. Corrugated metal arch pipe may be used where head room, fill and flow conditions of the tributary warrant it with the approval the Town of Wake Forest Engineering staff.
- B. All concrete pipe to be used shall be either etched "**RC X**" (where **X** represents the class pipe) or marked visibly and legibly according to the following:
  - 1. Stamp location: spigot end of pipe on inside.

2. Stamp size stenciled letters: 1-1/2" in height minimum.
3. Code Class 3 Reinforced Concrete: TWF-RC-3
4. Code Plain Concrete: TWF-P
5. Stamp color: fluorescent orange or red.

Unmarked pipe will be allowed only if the manufacturer furnishes a certified statement on the entire shipment and etchings are placed on each pipe joint.

**Table 2.23 Storm Drainage Pipe Policy**

Location on Drainage Course	Type of Pipe	Installation Requirements	Maintenance Responsibility	Who Pays Pipe & Material Costs	Who Pays Installation Cost
Driveway	RCP or Plain if diameter is 12" ID or under	Owner sets grade, Town checks grade and owner meets conditions of driveway permit	Town will maintain clear flow – owner replaces if pipe is damaged beyond use	Property Owner	Property Owner
Roadside Ditch	RCP or Plain if diameter if 12" ID or under	Per Section 2.10.3, Pipe Policy	Town will maintain clear flow – owner replaces if pipe is damaged beyond use	Town except in new Subdivision developments	Town except in new subdivision developments
Cross Street Culverts	RCP, Reinforced Concrete Box Culvert	Set by Town Public Works & Utilities Director	Town	Town except in new Subdivisions developments	Town except in new subdivision developments
Off Right-of-way Ditches (carrying public water)	RCP, Double Walled Corrugated HDPE, Conc. Lined channels, gabions, or other approved structure	Set by Town Public Works & Utilities Dir., Storm Drainage Policy, Subdivision Reg., if new development.	Town if installed by the Town pursuant to street drainage policy.	Property Owner	Town if installed under storm drainage policy
			Town if installed by developer under subdivision reg. and accepted by Town.		Owner if installed according to subdivision reg.
Note: All construction and installation of storm drainage structures is subject to the Manual of Specifications, Standards and design of the Town of Wake Forest and the approval of the Town of Wake Forest Engineering staff.					

### 2.10.3 PLACEMENT OF ROADSIDE DITCH PIPE

The following will apply on all concrete pipe installed in a roadside ditch were the ditch serves the function of draining the roadbed:

- A. Bedding shall be in conformity with paragraph 2.4.6.L, which also stipulates that all but the bottom 2-inch of the pipe joint (as measured across the diameter of the pipe) shall be sealed in accordance with Technical Specification 02700, Storm Drainage, paragraph 3.3.B, "Bedding Rigid Pipe."

For rigid pipe, refer to Standard Detail 2.53 for depth of bury and bedding requirements.

- B. All grades will be set by the Owner and checked by the Town.
- C. The property Owner must apply for a permit and bear cost of installation.
- D. Pipe cover shall be a minimum of 6-inches.

### 2.10.4 PLACEMENT OF OTHER PIPE

All other bedding of storm culverts shall be according to the Technical Specifications.

## 2.11 APPLICATION PROCEDURE

Application for storm drainage improvements shall be made on forms available from the Public Works and Utilities Department (see sample form below).

Figure 2.16 Sample Storm Drainage Application Form

### APPLICATION FOR STORM DRAINAGE PARTICIPATION TO THE DEPARTMENT OF PUBLIC WORKS AND UTILITIES OF THE TOWN OF WAKE FOREST:

The undersigned (the Applicant, whether one or more) hereby makes application to the Town of Wake Forest (the Town) to participate with the Applicant under principles set forth in the Town's Policy regarding installation of storm drainage on private property (the Policy) in the installation of a storm drain crossing the property of the Applicant at:

within the Town corporate limits, and herewith delivers to the Town the non-refundable sum of \$50 to cover the Town's cost of processing this Application, which sum the Applicant understands is non-refundable. If the Town constructs the project, the application fee shall apply to the property Owner(s) cost. The Applicant does hereby represent as follows:

1. The Applicant has read and is familiar with the Town's Policy, and storm drain, if installed, will carry storm drainage water discharged from an existing Town street or Town streets.
2. The proposed storm drain, if installed, is to be installed in accordance with specifications as approved by the Town.
3. The Applicant acquired ownership to the property on which the proposed storm drain and the proposed easement is to be located as follows:

**NOTE: ALL OWNER(S) MUST SIGN!**

GRANTOR/GRANTEE		DATE OF DEED	RECORDED	
			BOOK	PAGE NO.
1				
2				
3				
4				
5				
6				
7				
8				

4. In the event the Town agrees to participate with the Applicant in the installation of said proposed storm drain, then prior to such participation the Applicant will execute and deliver to the Town such necessary perpetual easement as specified by the Department of Public Works and Utilities for the installation and maintenance of said proposed storm drain, which easement shall incorporate the terms and conditions under which said storm drain is to be installed and the basis on which the Town shall participate therein.

This \_\_\_\_\_ day of \_\_\_\_\_, 20\_\_\_\_\_

Signature of Applicant(s): (If corporation, must be executed in corporate name by an officer).

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Certified and approved by the Department of Public Works and Utilities.

_____	_____
Director of Public Works and Utilities	Date



**2.12 STORMWATER APPENDIX****A. Stormwater Management Permit Application/ Low Density Supplement Form**

Use latest “State Stormwater Permit Application” forms from NCDENR website:

[http://portal.ncdenr.org/web/1r/state-stormwater-forms\\_docs](http://portal.ncdenr.org/web/1r/state-stormwater-forms_docs)

**B. Stormwater Management Checklist, *Form SW110*****C. Example Stormwater Operation And Maintenance Agreement****D. As-Built Certification Form, *Form SW200*****E. Annual BMP Inspection/ Certification Form, *Form SW210***